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EFFECTS OF INDUSTRIAL EFFLUENTS ON WATER QUALITY, SEDIMENTS AND BENTHOS OF THE ST. LAWRENCE RIVER AT MAITLAND, ONTARIO

October 1978

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Environment

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Andrew S. Brandt
Minister

Gérard J. M. Raymond
Deputy Minister

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EFFECTS OF INDUSTRIAL EFFLUENTS ON WATER QUALITY, SEDIMENTS AND BENTHOS OF THE ST. LAWRENCE RIVER AT MAITLAND, ONTARIO

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Background information on the area was freely supplied by D.S. Lee of DuPont of Canada Limited. Identification of invertebrate species was carried out by D. Craig, statistical analyses were performed by S. Mathai and graphics were executed by R.A. Winson's drafting staff.

SUMMARY

DuPont of Canada Limited

Two zones of influence were found to be associated with the DuPont of Canada plant in 1975.

The zone of influence associated with the DuPont tetraethyl lead outfall extends east along the north shore of the river for a distance of approximately 1 km. This zone is characterized by elevated levels of lead in the sediments. The benthic community is severely depressed near the outfall and moderately impaired in the downstream portion of the zone.

The zone of influence associated with DuPont's former monomer outfall is the most extensive in the study area extending at least 2 km southeast from the outfall and predominantly affecting the deep (18 m) region of the river. Sediments in this zone are characterized by elevated levels of cobalt, zinc and iron. The former monomer effluent was apparently responsible for significantly altering the zoobenthic community in the area by decreasing its species diversity, depressing the number of taxa and drastically reducing the population of the snail *Bithynia tentaculata*. No recovery was evident at a distance of 2 km from the outfall suggesting that this zone of influence extends beyond the study area.

The treated monomer effluent, discharged presently side by side with the tetraethyl lead effluent, does not appear to have had an adverse effect on sediment quality, as yet.

Genstar Chemical Limited

Severe impairment of the benthic community and highly elevated levels of nitrogenous compounds, COD, and loss on ignition were found in the sediments in the immediate vicinity of the outfall in 1975. High levels of mercury, copper, zinc, and lead also were recorded in the area. Moderate impairment, as characterized by reduced zoobenthic species diversity and elevated levels of nitrogenous compounds and COD in sediments, was detected downstream from the outfall for a distance of approximately 2 km. This zone of influence is confined to the north shore of the St. Lawrence River and also exhibits elevated levels of ammonia, organic nitrogen and nitrates in the water column.

RECOMMENDATIONS

The findings of this study have led to the following recommendations:

1. Existing Ministry objectives for havy metal concentrations in DuPont Co. industrial effluents should be adhered to. Notwithstanding action taken to achieve these objectives, the best practicable treatment for high strength component waste streams should be instituted. Specifically:

    (a) The DuPont Co. effluent from its tetraethyl lead production process should receive treatment and/or process modification to reduce lead to absolute minimum levels.

    (b) The composition of the treated effluent from the DuPont Co. monomer production process should be investigated for possible high levels of zinc and iron. If these heavy metals are found in excessively high concentrations, treatment of the effluent and/or process modifications should be initiated.

2. Measures should be taken at the DuPont Co. sewage treatment plant to ensure adequate effluent disinfection.

3. Water quality deterioration caused by high nitrogen outputs from Genstar Limited and DuPont Co. should be remedied through an improvement in the nitrification process at the wastewater treatment facilities using best practicable treatment technology.

4. The possibility if phenolic discharges from DuPont Co. and Genstar Chemical Limited should be further investigated. If phenolic compounds are found in excessively high conventrations, treatment of the effluent and/or process modifications should be initiated in order to reduce these concentrations to levels in compliance with existing Ministry objectives.

5. The composition of the treated effluent from Genstar Chemical Limited should be investigated for possible high levels of mercury, copper, zinc and lead. If these heavy metals are found in excessively high concentrations, treatment of the effluent and/or process modifications should be initiated.

ADDITIONAL STUDY

Additional studies are required to properly assess the zone of influence associated with the former DuPont Co. monomer outfall and to monitor the possible toxic effect of the new monomer effluent on the aquatic biota.

INTRODUCTION

In 1975, the Water Resources Branch of the Ministry of Environment initiated a study of the St. Lawrence River at Maitland, Ontario, aimed at:

1. Determining the extent of water and sediment quality impairment associated with effluent discharges from Genstar Chemical Limited and DuPont of Canada Limited.

2. Assessing the effects of these discharges on the St. Lawrence River benthic community, sediments and water quality.

3. Identifying the need for abatement measures.

DESCRIPTION OF STUDY AREA

The area under investigation is located on the St. Lawrence River at Maitland, Ontario, approximately 15 km east of Kingston (Figure 1). Two industries are located in the area:

(a) Genstar Chemical Limited operates a nitrogen complex producing ammonia, hydrogen, nitric acid, ammonium nitrate, urea and nitrogen solutions and discharges its wastes (0.25 mgd) through process wastes outfall 'N' (Figure 2a).

(b) DuPont of Canada Limited operates a predominantly petrochemical complex, which produces nylon intermediates, tetraethyl lead, acrylic fibres, spendex fibres and freons. The wastes from the monomer processes (0.35 mgd) are discharged through outfall 'M' and wastewater from the tetraethyl lead plant (2 mgd) together with cooling water (32 mgd) is discharged through crib ditch outfall 'L' (Figure 2a). A small sewage treatment plant (0.06 mgd) located on the DuPont site discharges through outfall 'S'.

The impact study of DuPont discharges is complicated by the fact that six months prior to the present survey, treatment of the monomer process wastes was initiated and that outfall locations were altered with the effect that:

(a) wastes from the tetraethyl lead production which previously were discharged through a 500' corrugated steel pipe, were redirected to the sewer carrying monomer process wastes;

(b) The process waste sewer was relocated 550' upstream from the old one and was replaced by two shorter (340' and 390') polyethylene pipes.

The locations of new and old DuPont outfalls are given in Figure 2b.

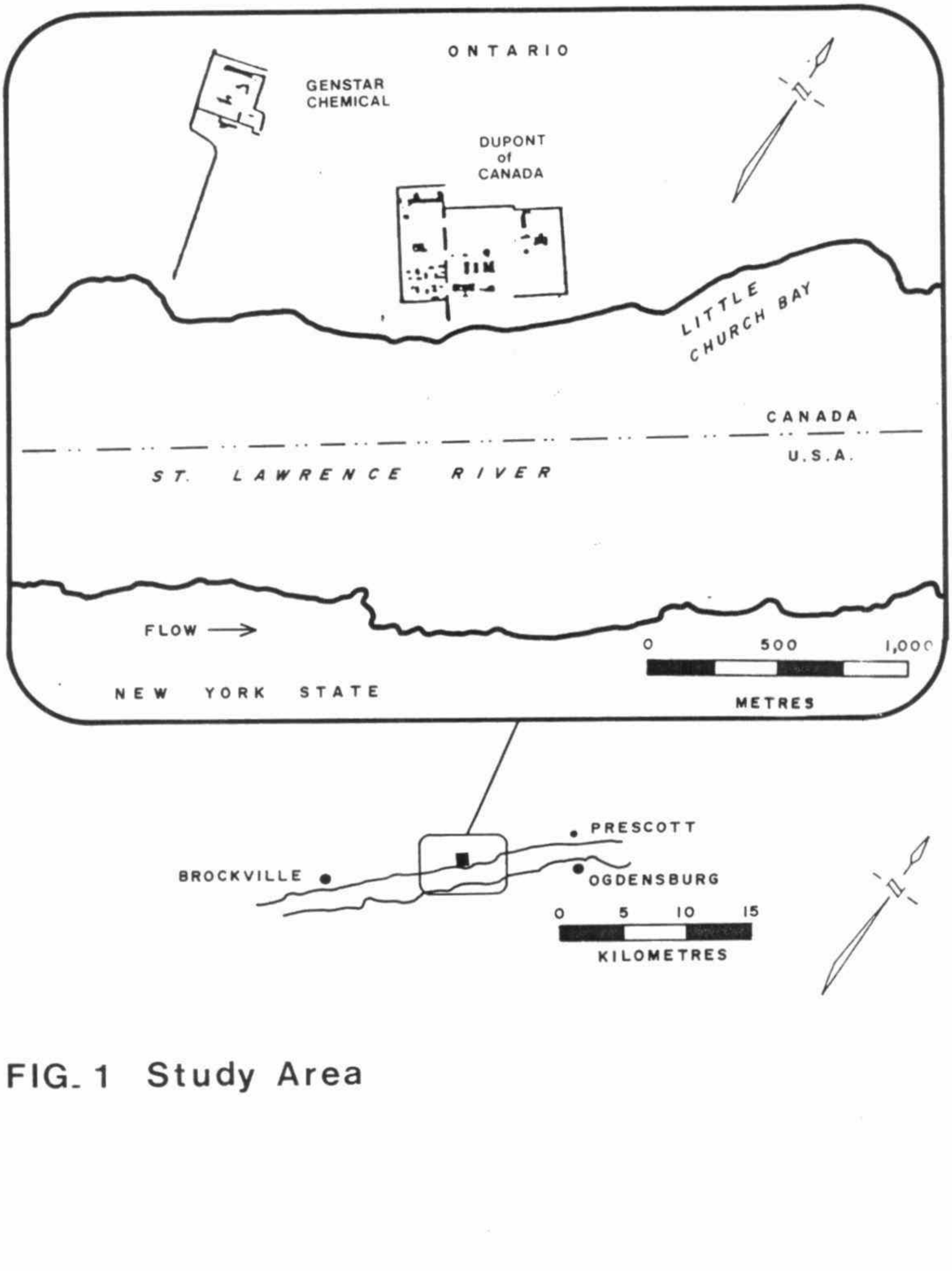
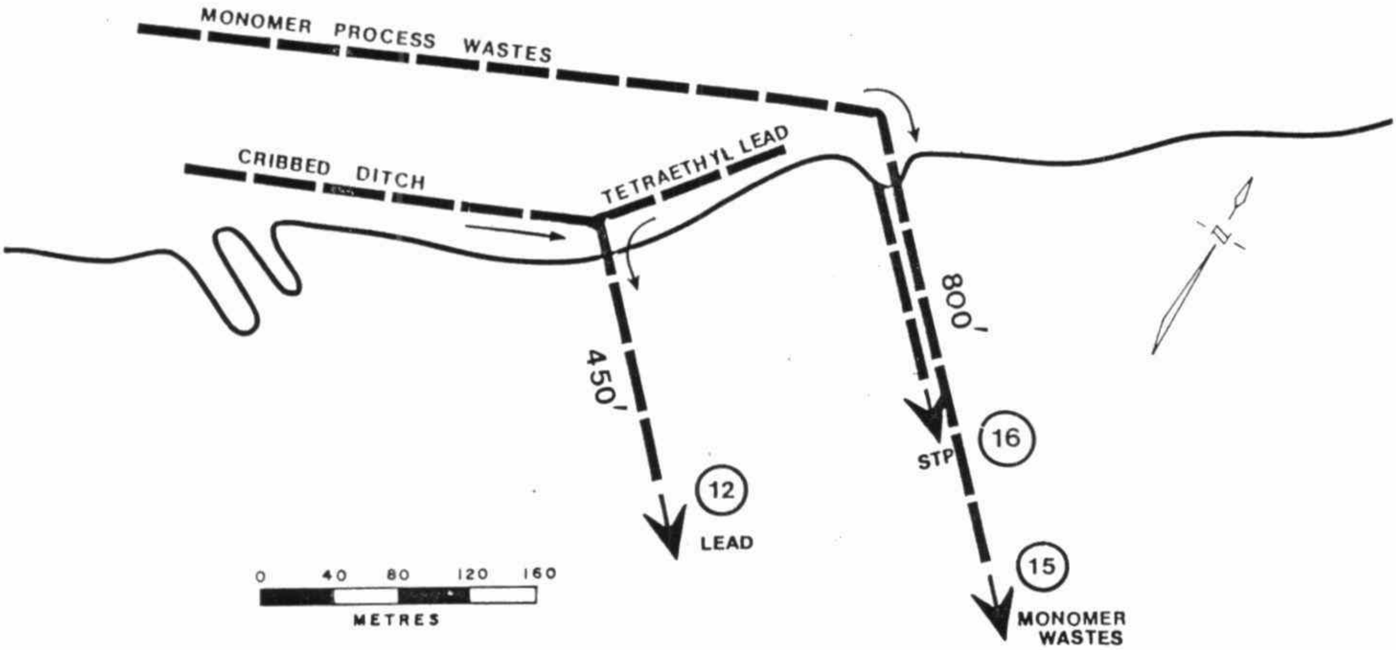
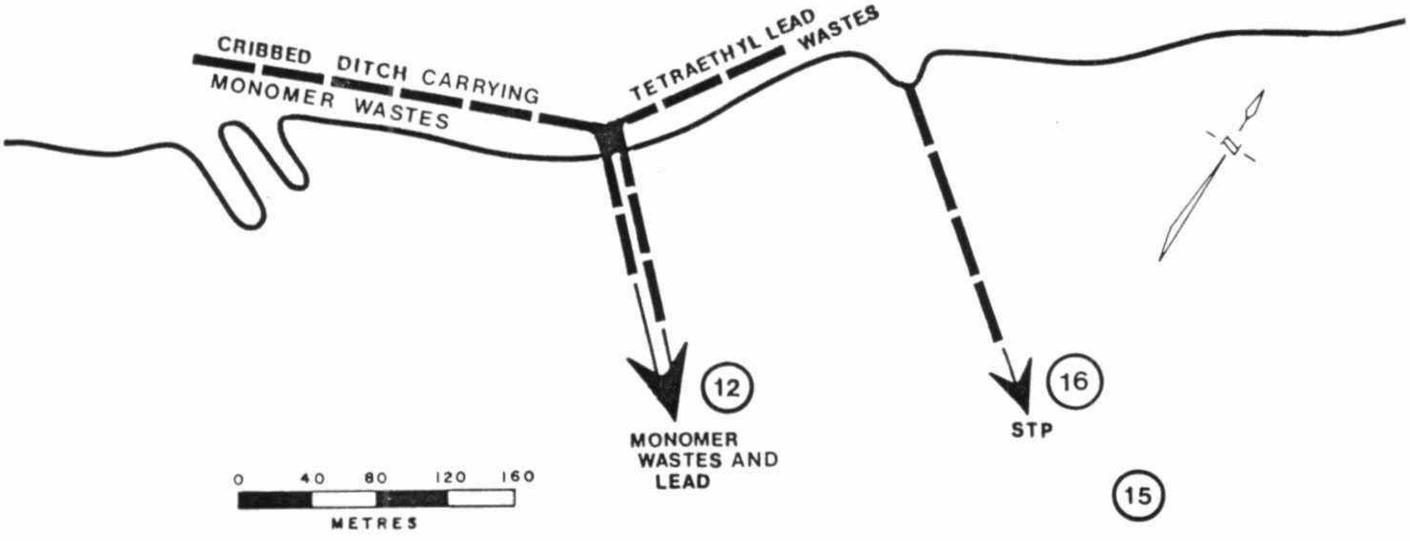


FIG. 1 Study Area



(a) OLD OUTFALL LOCATIONS



(b) NEW OUTFALL LOCATIONS

FIG.2 Location of sampling stations relative to old and new Dupont outfall locations

SURVEY OUTLINE

Sampling was carried out in the summer of 1975. Twenty six sediment and zoobenthos stations were established along transects aligned perpendicular to shore. Stations were located at depth contours of 2 m, 9 m and 18 m (Figure 3). The location of transects was as follows:

Transect A:	500 m upstream from Genstar Chemical Limited outfall (considered background for the study area)
Transect B:	near Genstar Chemical Limited outfall.
Transect C:	1000 m downstream from Transect B
Transect D:	near new DuPont monomer and tetraethyl lead outfalls.
Transect E:	near old DuPont monomer outfall.
Transect F:	500 m downstream from transect D
Transect G:	1000 m downstream from transect D
Transect H:	2000 m downstream from transect D

Four Shipek grabs were taken at each station. One grab was subsampled and sent to the laboratory for particle size analysis and determinations of nutrients (Total P, Kjeldahl N), loss on ignition, chemical oxygen demand (COD) and six heavy metals (Fe, Zn, Hg, Pb, Cu, Co). The other three samples were separately screened in the field through 200 u mesh Nytex netting and preserved in 10% formalin. The invertebrates recovered were subsequently enumerated and identified to the level of species where possible.

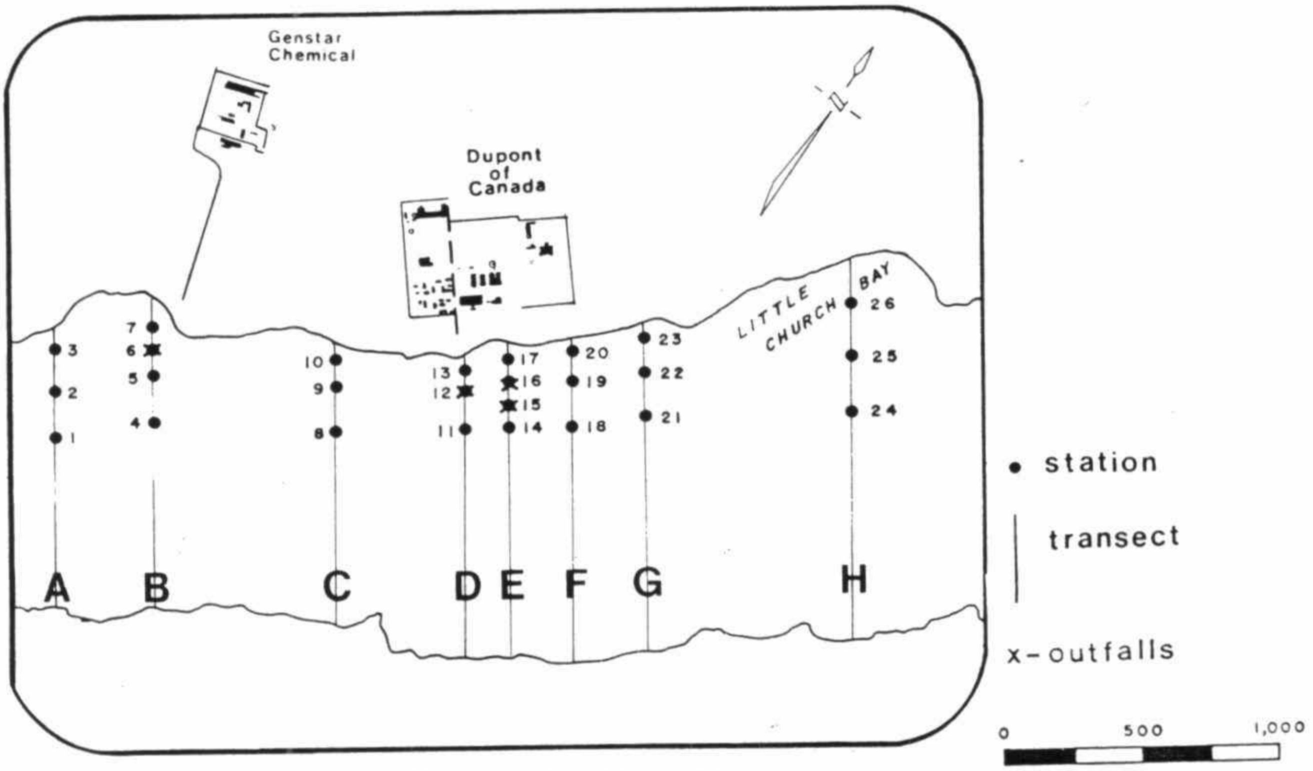
Diversity of the zoobenthos was computed according to the Simpson-Gini index:

$$\tilde{D} = 1 - \Sigma \{ | ni(ni) | / | N(N-1) | \}$$

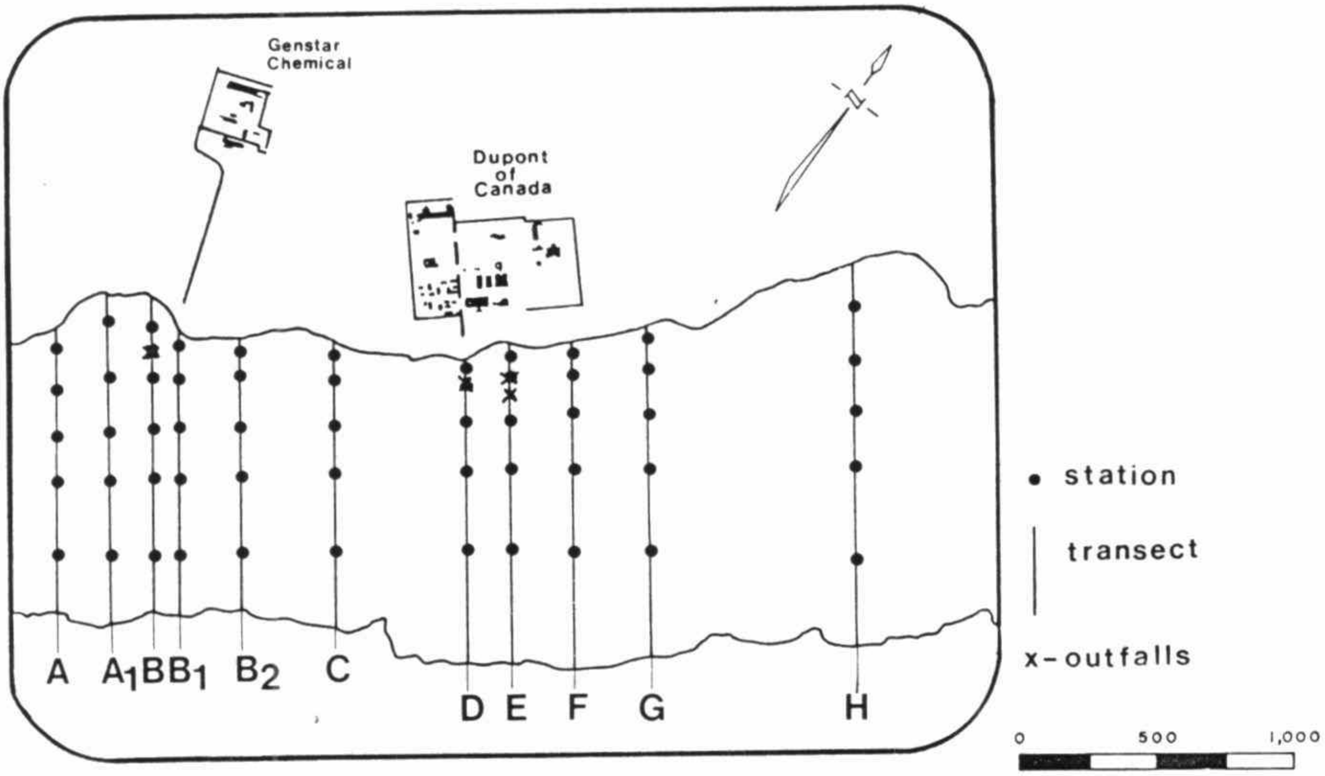
where n_i is the number of individuals in species i and N the total number of individuals in the sample.

This index is one of several heterogeneity indicies which measure the probability that two individuals selected at random from a sample will belong to the same species. The index has been adjusted for finite sample size.

Water quality investigations were conducted concurrent to sediment and benthos studies. A total of 54 stations were established, 26 of which corresponded with the sediment stations and the remainder covered the southern shoreline of the river (Figure 3). during the survey, both industries were discharging atypical waste loads. Genstar Chemical Limited was testing a new nitric acid plant and likely was discharging liquid wastes high in nitric acid, urea,



Sediment and Benthic Stations



Water Quality Stations

FIG. 3 LOCATION OF SAMPLING STATIONS

ammonium nitrate and free ammonia. DuPont was intermittently by-passing 20% of its process wastes while experiencing denitrification problems and consequently was discharging effluents high in organic nitrogen and BOD.

Since the water quality data presented in this section may reflect the irregularities described above it is possible that this information is not truly representative of average water quality conditions in the area. Consequently, the report will place emphasis on sediment and benthic information as these data reflect the long term conditions prevailing in the area.

RESULTS

I WATER QUALITY

(a) Nutrients

Total nitrogen levels were highly elevated throughout the Canadian nearshore zone downstream from both industrial complexes (Figure 4). Although the total nitrogen concentration in the Genstar effluent was slightly higher (1367 mgN/l) than that in the DuPont treated process waste (995 mgN/l), the areal extent of the plume associated with the DuPont discharge was considerably larger (Figure 4). This discrepancy suggests the existance of an additional nitrogen load discharged by the DuPont plant and not monitored during this study. This load likely consisted of untreated process waste discharged by DuPont through the old monomer outfall while experiencing denitrification problems.

Several violations of MOE water quality criteria were observed during the survey. Ammonia levels in excess of the criteria for public water supplies (0.5 mg/l) were detected for a distance of 1 km and 0.5 km downstream from the Genstar and DuPont outfalls, respectively (Figure 5). Nitrate levels in excess of the 10 mg/l criterion were recorded in Little Church Bay (Figure 6). This embayment exhibited the highest levels of total nitrogen recorded in the study area. Accumulation of wastes in Little Church Bay is likely brought about by limited water exchange and poor circulation characterizing the embayment.

Whereas ammonia and nitrates were the major nitrogen components detected immediately downstream from the outfalls (Figure 5, 6), organic nitrogen and nitrates composed most of the total nitrogen in Little Church Bay (Figure 7). It would appear that in the embayment, ammonia was being transformed by nitrifying bacteria to nitrates and subsequently incorporated into living organisms as organic nitrogen. This is further supported by high numbers of heterotrophic bacteria found in Little Church Bay which were likely involved in the nitrification process (Figure 13). Although nitrogen levels on the north shore of the river were elevated, no transboundary movement was detected.

Elevated levels of total phosphorus were detected throughout the nearshore zone of the river downstream from DuPont outfalls (Figure 8). Out of all the outfalls tested during this survey, DuPont process wastes effluent contained the highest level (1.78 mgP/l) of total phosphorus. Phosphorus levels, downstream from the DuPont outfall, remained above .030 mgP/l for a distance of at least 2 km. No transboundary movement of phosphorus was detected in the area. The phosphorus loads discharged by Genstar Chemical Limited had little effect on phosphorus levels in the river.

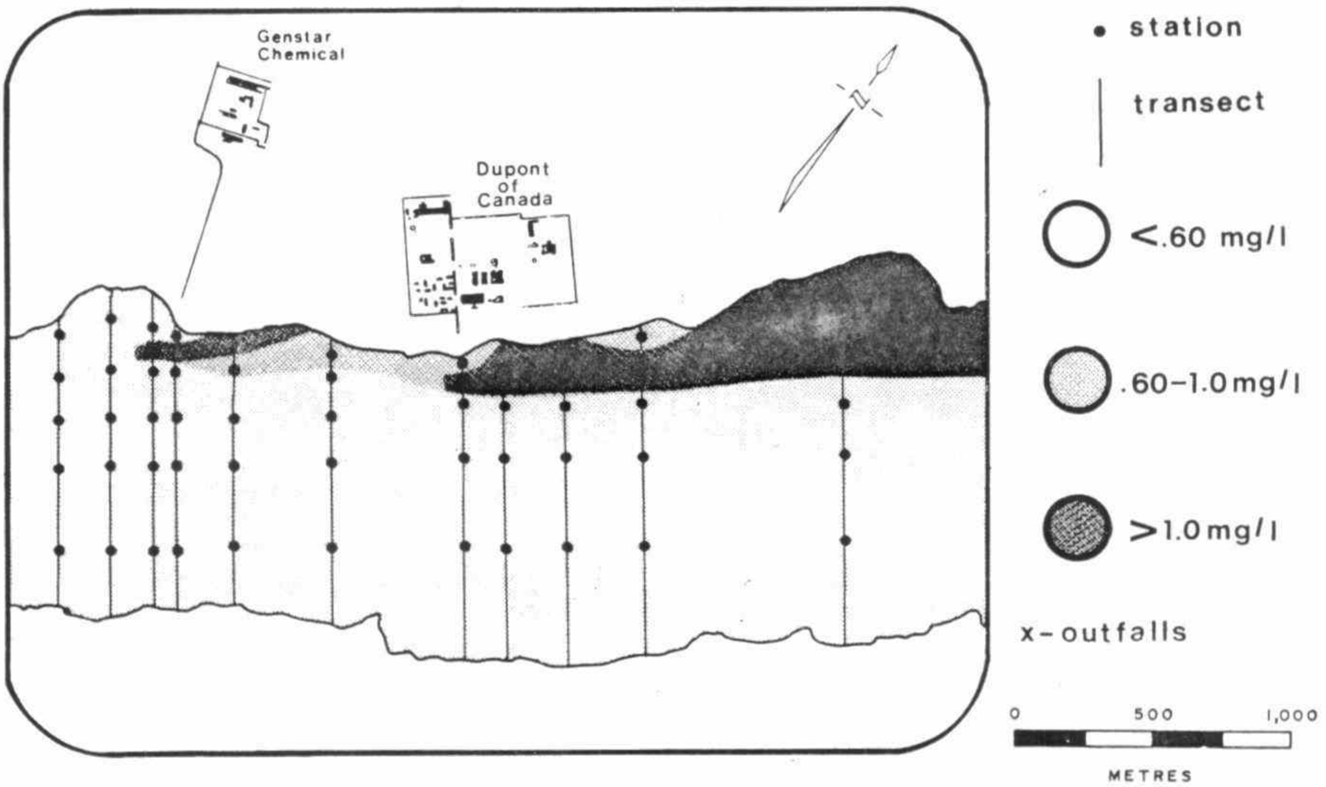


FIG. 4 Total Nitrogen Distribution in Water

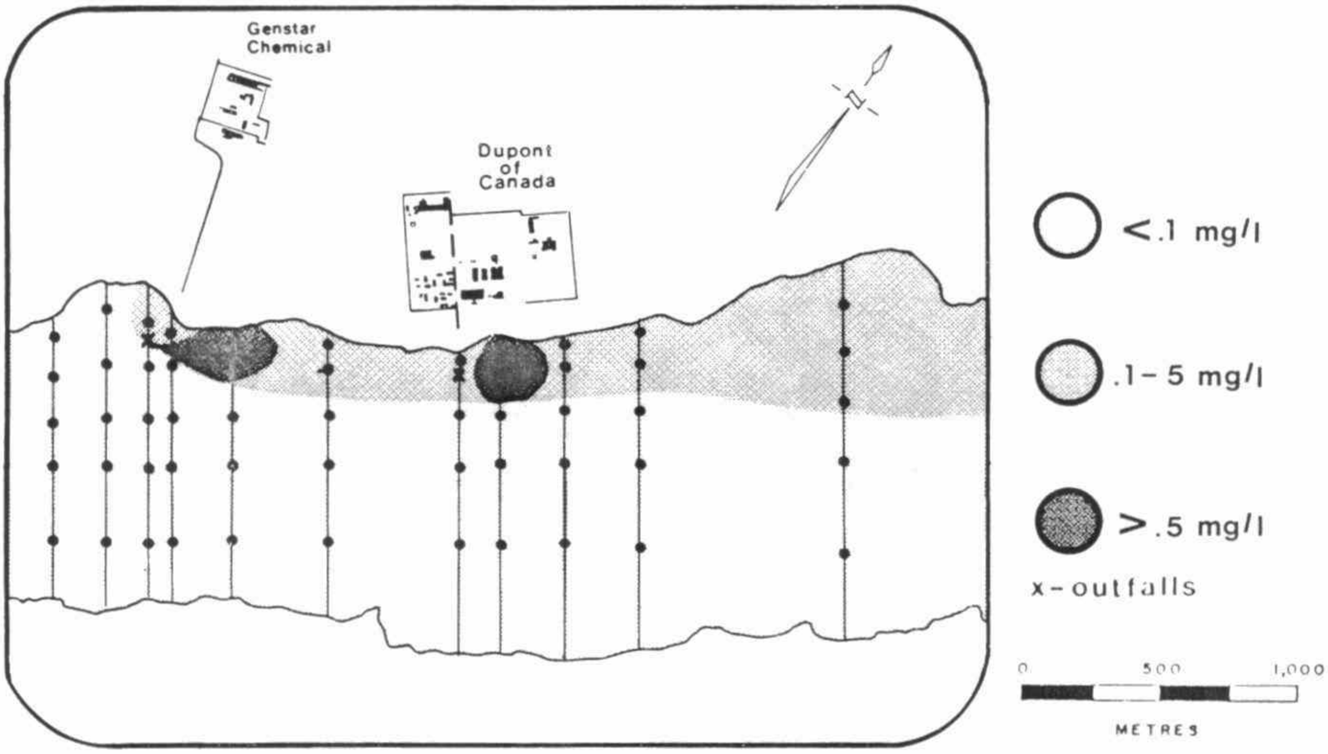


FIG. 5 Ammonia Distribution in Water

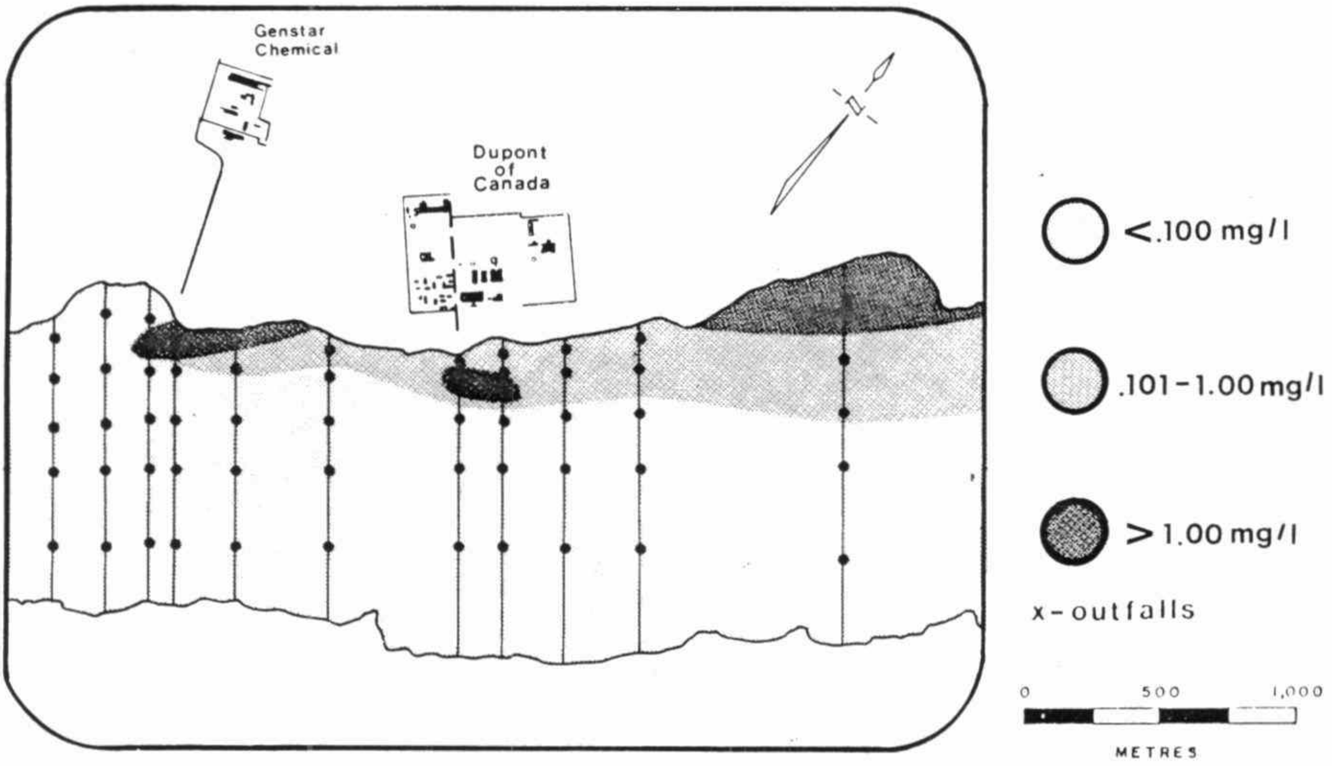


FIG. 6 Nitrate Distribution in Water

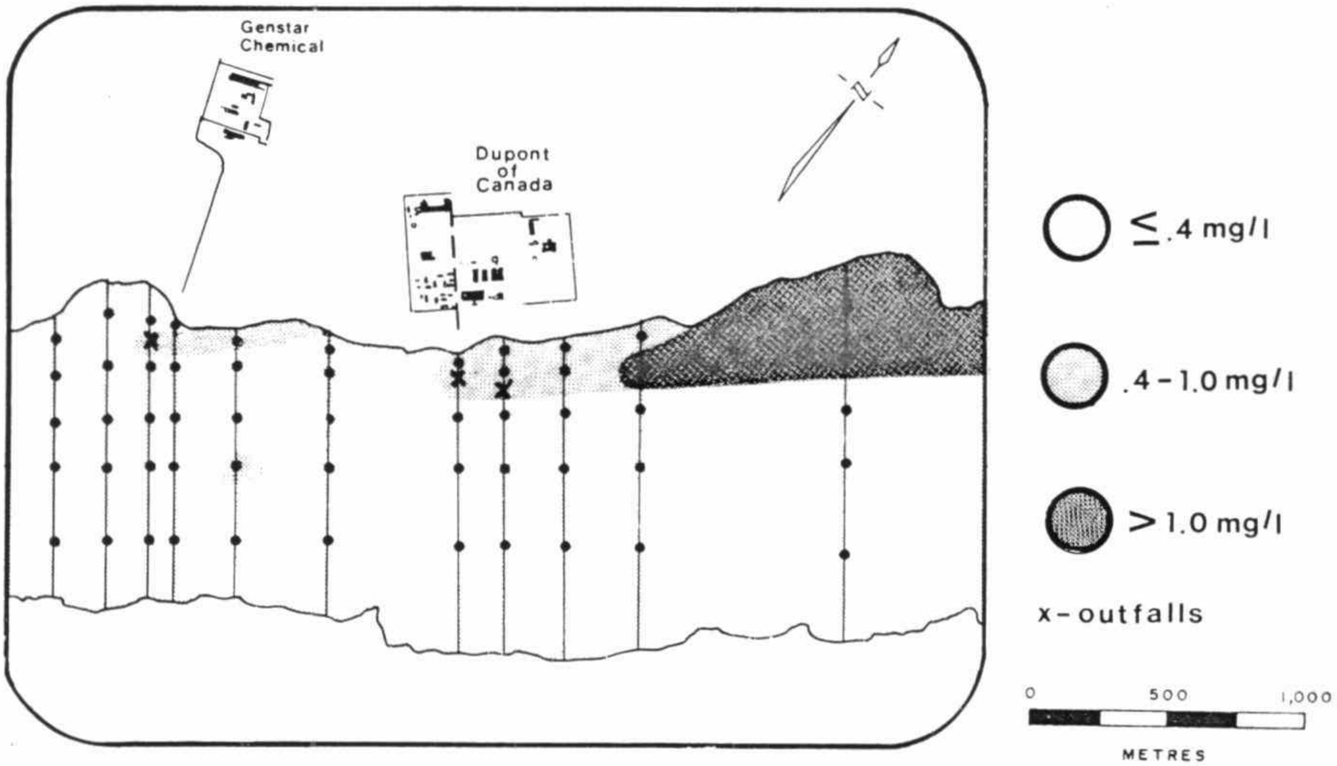


FIG. 7 Organic Nitrogen Distribution in Water

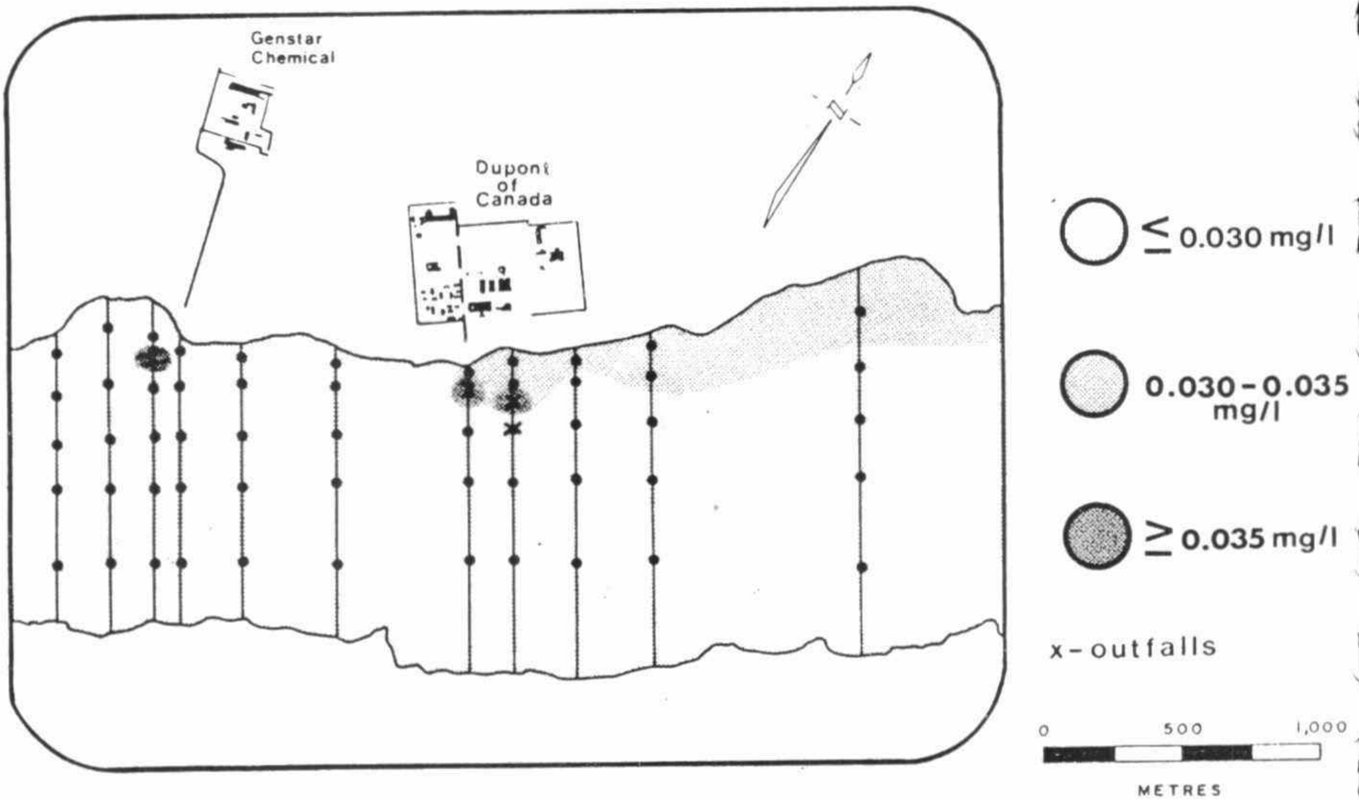


FIG. 8 Total Phosphorus Distribution in Water

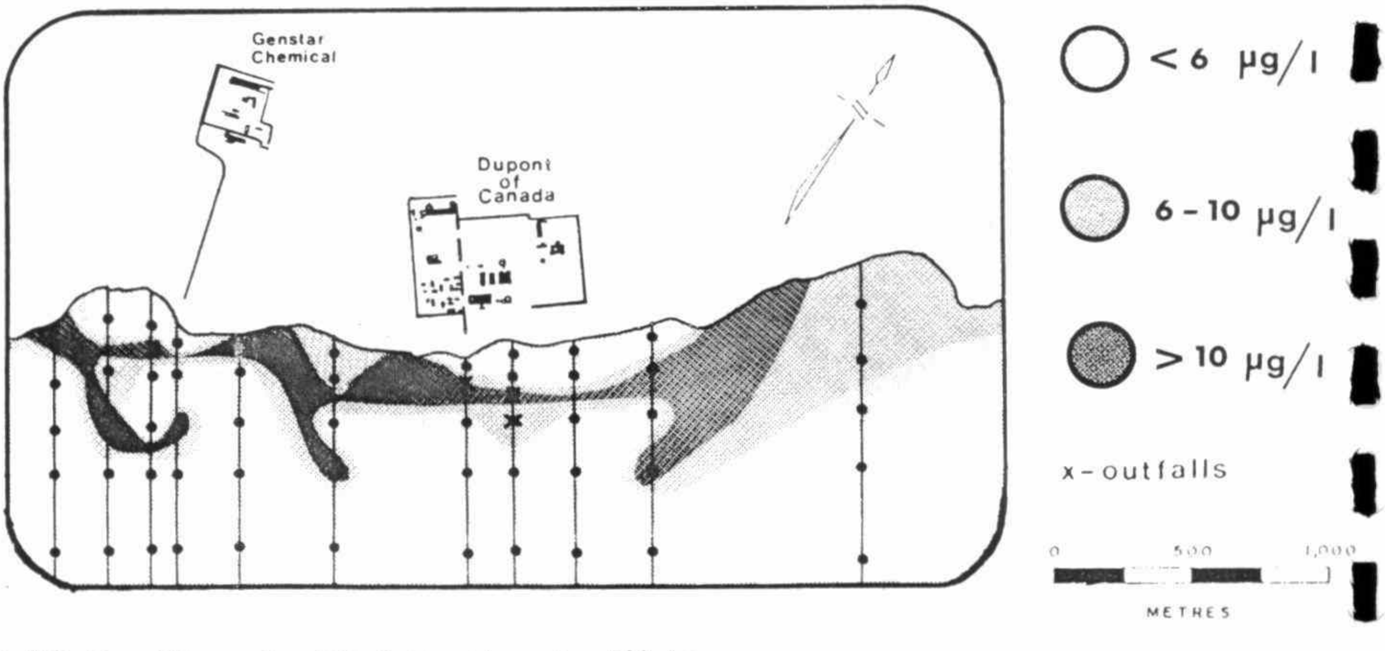


FIG. 9 Phenols Distribution in Water

(b) Phenolic Compounds

Nearly all stations sampled were found to have phenol levels in excess of the MOE water quality criteria for public surface water supplies (virtually absent) although the distribution of phenolic compounds in the study area was patchy (Figure 9). Levels above 6 ug/l were found throughout most of the Canadian nearshore zone. Highest concentrations of phenols in effluents were found in DuPont process wastes (188 ug/l) followed by Genstar Chemical Limited process wastes (38 ug/l) and DuPont crib ditch effluent (17 ug/l).

Since no known sources of phenol exist in the two processes, its presence in the area is enigmatic. It is possible that some raw materials such as cyclohexanes could have interferred with the phenol test. Further studies are required to investigate the occurrence of this contaminant. If the presence of phenols in the area is verified, a study of transboundary movement of this contaminant will be essential.

(c) Bacteria

Coliform levels downstream from the DuPont outfalls were only slightly elevated (Figure 10, 11) above background. Maximum levels recorded in the study area (250 total coliform organisms per 100 ml and 15 fecal coliform organisms per 100 ml were well within the 1000/100 ml and 100/100 ml criteria set out by MOE for total body contact recreation.

Alarmingly high Pseudomonas aeruginosa counts (Figure 12), however, indicate that those waters may pose a threat to human health. Pseudomonas is a pathogen known to be a primary invader in ear infections and a secondary invader in eye, nose and throat infections.

Almost the entire Canadian neashore zone downstream from Genstar Chemical and DuPont exhibited levels in excess of 2 Pseudomonas organisms/100 ml. Highest counts were found downstream from the DuPont outfall, where, for a distance of 1 km the mean Pseudomonas count was 47 organisms/100 ml with a maximum of 86 and a minimum of 18 organisms/100 ml.

Pseudomonas organisms found in the area most probably originate in sanitary wastes discharged by both Genstar Chemical Limited and DuPont of Canada. Genstar Chemical Limited operates a private STP (0.007 mgd) which discharges wastes into the process waste sewer. Wastes from DuPont STP (0.06 mgd) are discharged through a separate sewer (Figure 2b). The present treatment system appears inadequate in reducing Pseudomonas counts to acceptable levels.

Elevated levels of heterotrophic bacteria were found in the Canadian nearshore zone of the river, with especially high counts recorded in Little Church Bay (Figure 13). High hetertroph levels are indicative of enriched conditions. Levels in excess of 100,000 organisms/ml downstream from DuPont outfalls suggest that effluents high in organic matter are discharged by the plant. Nitrogenous wastes discharged by both industries also contribute to high heterotroph populations observed in the area.

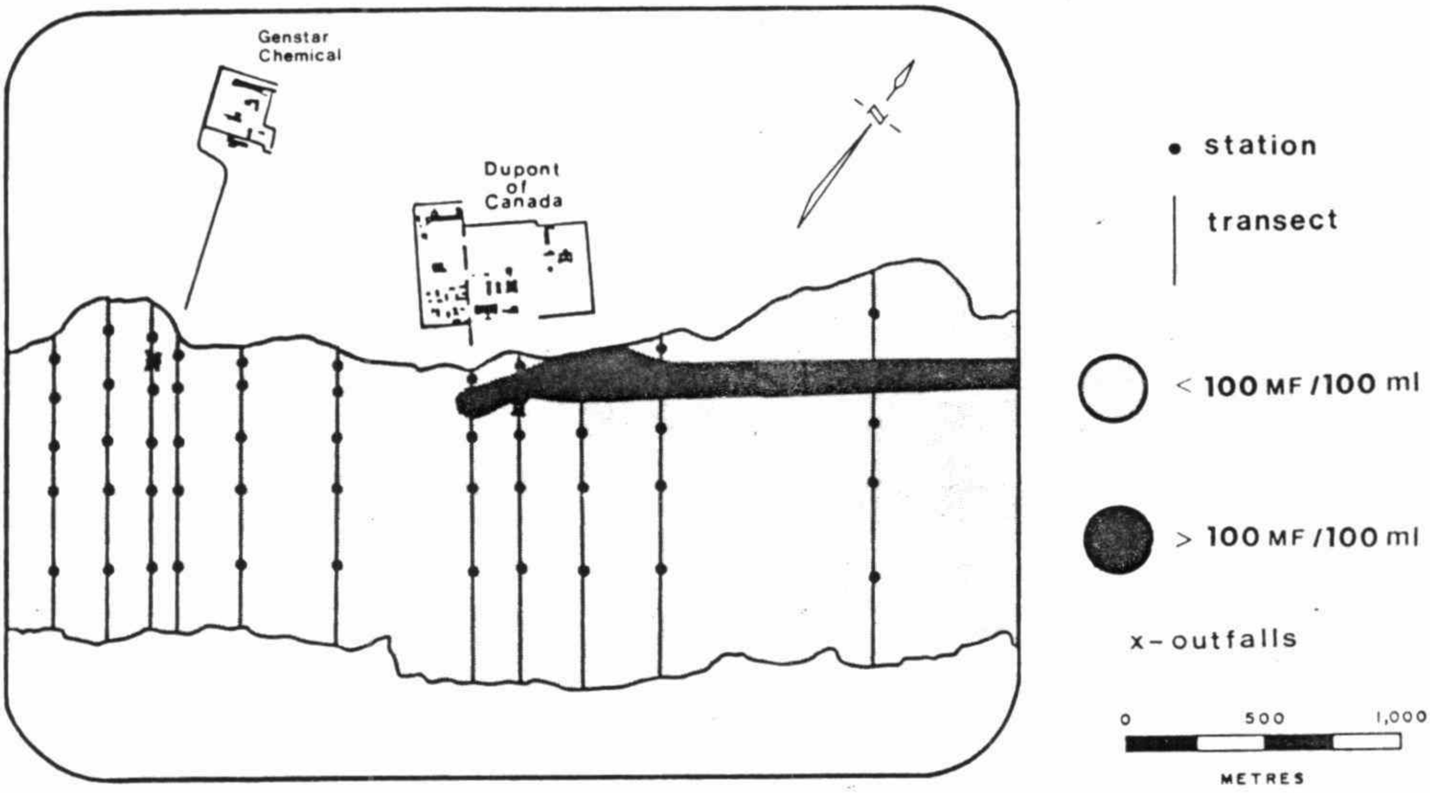


FIG.10 Total Coliform Levels in Water

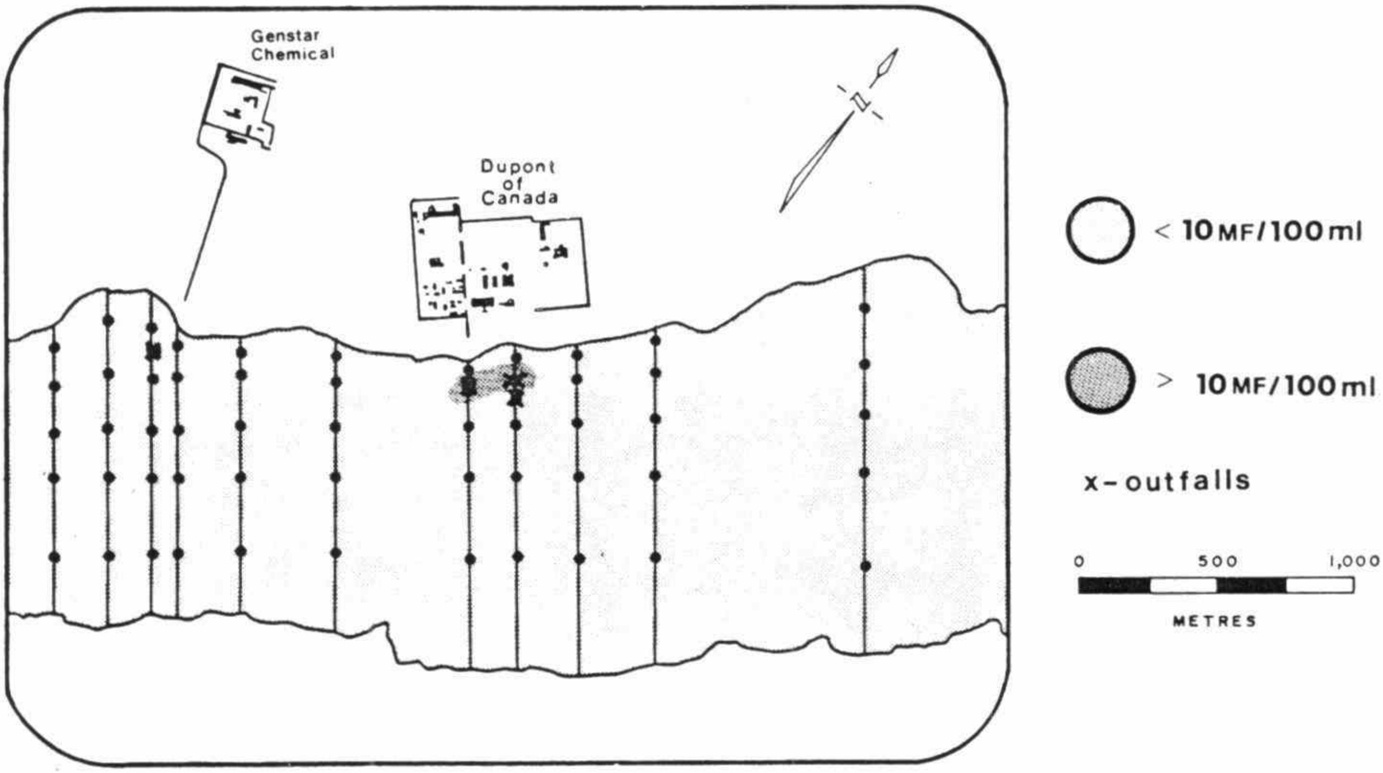


FIG. 11 Fecal Coliform Levels in Water

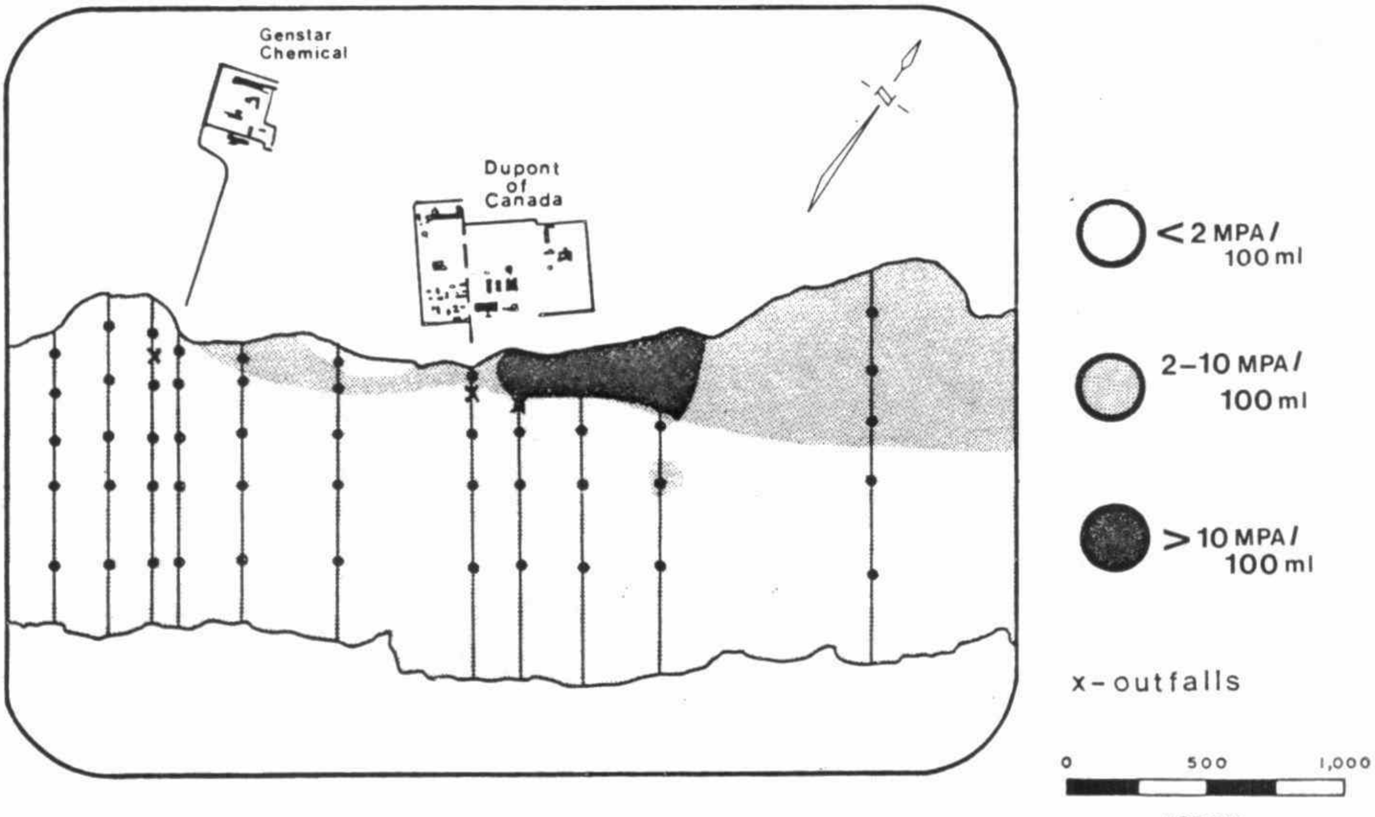


FIG. 12 Pseudomonas Levels in Water

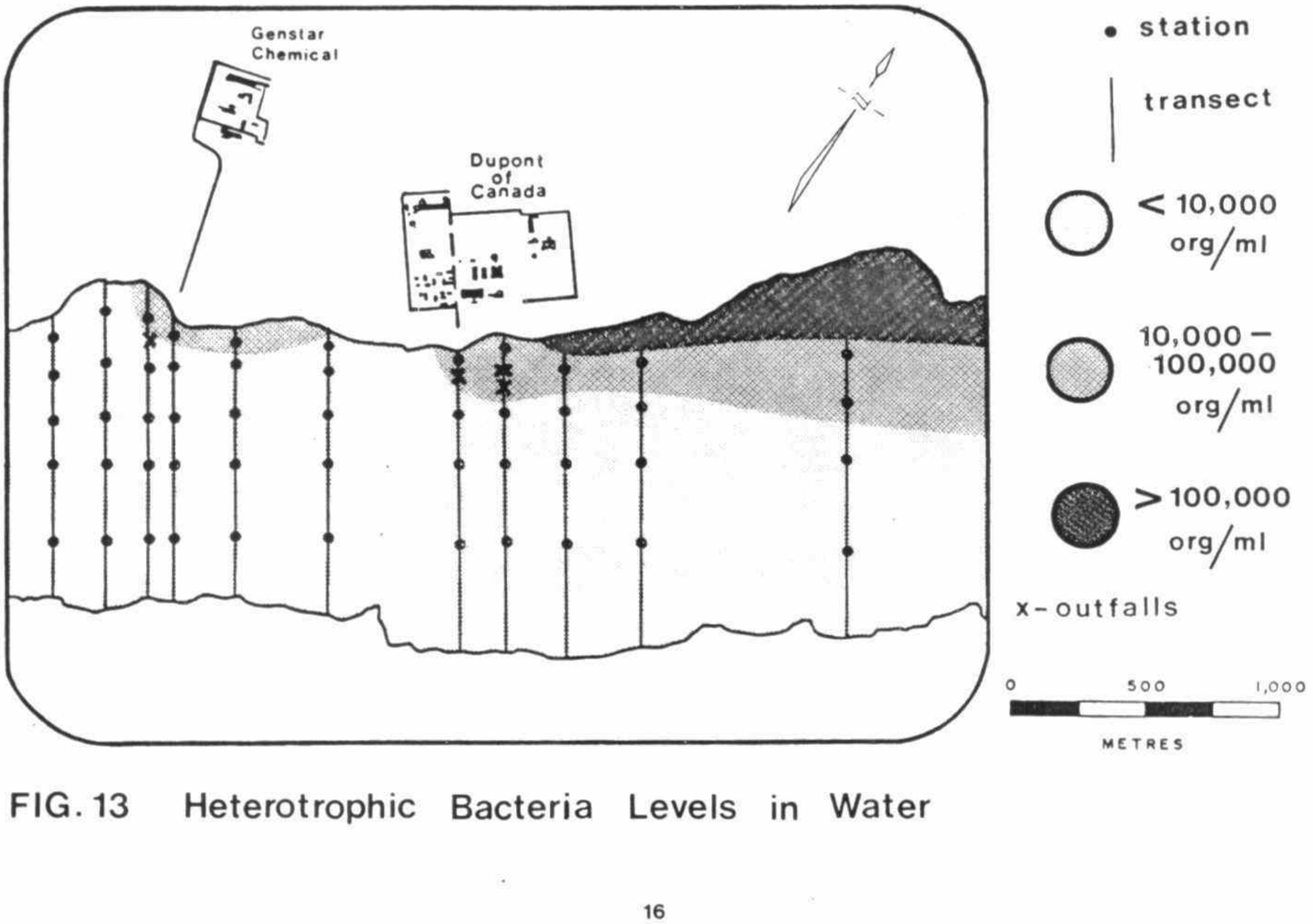


FIG. 13 Heterotrophic Bacteria Levels in Water

II SEDIMENT CHARACTERISTICS

(a) Sediment Texture

The textural composition of the samples has been calculated in terms of sand, silt and clay according to the Shepard (1954) classification (Figure 14). Sands and silty sands predominated in the area with coarser sand deposits occurring largely in the nearshore zone. The offshore deposits were composed predominantly of silty sand interspersed with patches of silt and clayey sands. The mean textural composition of these sediments is summarized in Table 1.

The distribution of sediment median grain size is shown in Figure 15. Most of the samples in the area fall within the fine sand range of 0.075 mm to 0.4 mm. In addition, one patch of gravel, one patch of medium coarse sand, and two patches of silt were detected through this form of analysis.

The Shepard (1954) classification was found to be a more senitive technique than median grain size analysis in determining textural characteristics of sediments. This classification, however, failed to distinquish between gravel and sand particles. This is a shortcoming which can be overcome with the median grain size analysis.

It follows that a textural composition of sediments is best described using a combination of the two types of analysis.

(b) Sediment Chemistry

This section deals with the chemical composition of sediment within the study area. Transect A, located upstream from the discharges, is considered to represent background values for the area based on an average of the three background stations. These levels are only approximations of background conditions, however, since they may overestimate the true background for the area. It would appear from the data that transect A is somewhat affected by the Genstar Limited Chemical discharge possibly as a result of a back-eddy or a countercurrent operating in the nearshore zone of the river.

Since a true background estimate is unavailable, the degree of sediment contamination will be discussed with respect to existing guidelines and criteria. Where available, MOE criteria are used and are supplemented by EPA guidelines only where no MOE criteria exist. A summary of criteria discussed in this section appears below.

1. Ontario (MOE) Criteria of Acceptability for Open Water Disposal of Dredged Materials (IWG, 1975).

Parameter	Maximum Permissible Concentration
Loss on Ignition	6 %
COD	50 g/kg
Total Kjeldahl Nitrogen	2 mg/g
Total Phosphorus	1 mg/g
Total Mercury	0.3 mg/kg

2. United States (EPA) Criteria of Acceptability for Open Water Disposal of Dredged Materials (IWG, 1975).

Parameter	Maximum Permissible Concentration
Lead	50 mg/kg
Zinc	50 mg/kg

3. Suggested guidelines (EPA) for evaluation of Great Lakes Sediments in Region V. (1975).

Parameter	Nonpolluted	Moderately Polluted	Heavily Polluted
Iron	17 g/kg	17-25 g/kg	25 g/kg

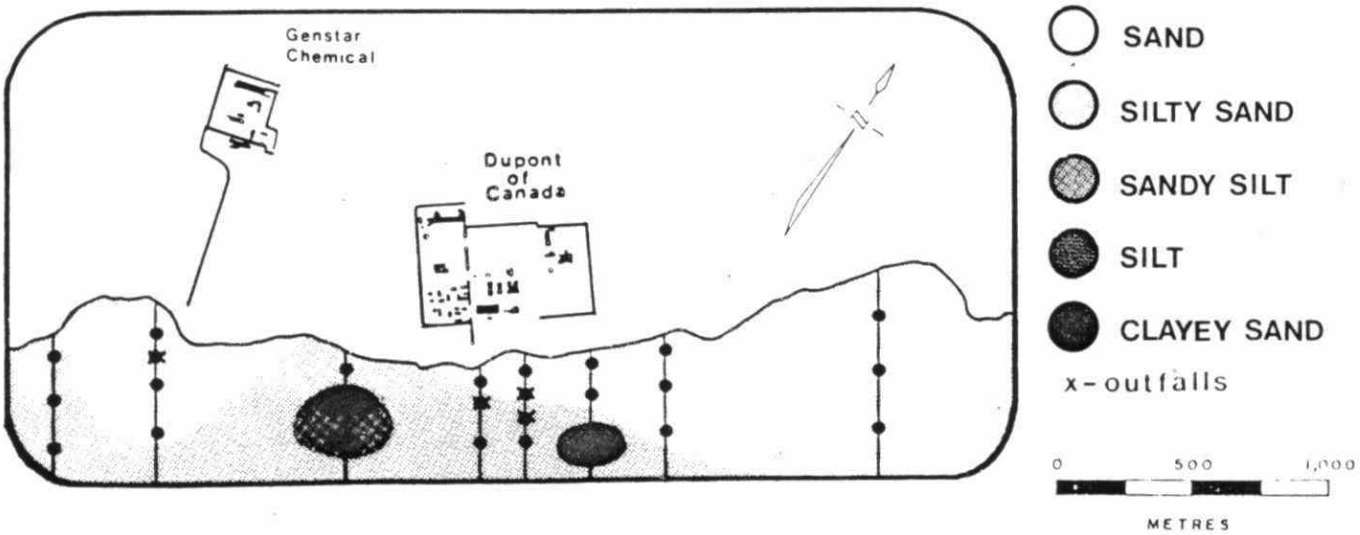


FIG. 14 Sediment Distribution Based on Shepard 1954 Classification

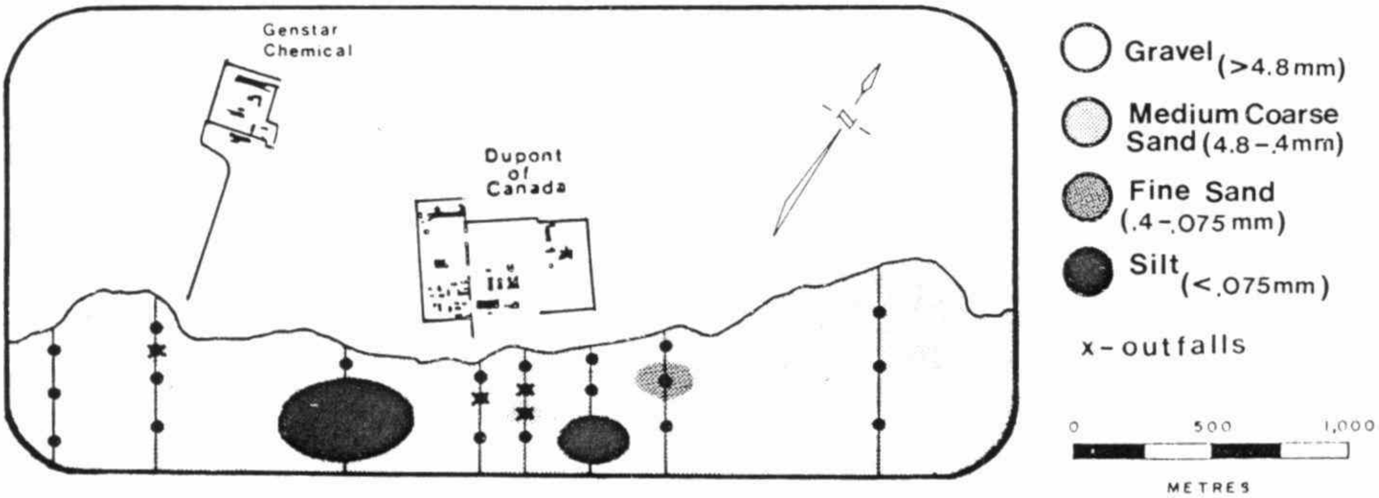


FIG. 15 Distribution of Median Grain Size of Sediments

TABLE 1 TEXTURAL COMPOSITION OF SEDIMENTS, MAITLAND, ST. LAWRENCE R. 1975

	% COMPOSITION			CLASSIFICATION
STATION	SAND	SILT	CLAY	SHEPARD 1954
1	68	30	2	silty sand
2	71	27	2	silty sand
3	67	31	2	silty sand
4	82	16	2	sand
5	86	12	2	sand
6	90	8	2	sand
7	77	21	2	sand
8	28	70	2	sandy silt
9	16	82	2	silt
10	69	29	2	silty sand
11	73	25	2	silty sand
12	56	40	2	silty sand
13	80	18	2	sand
14	72	26	2	silty sand
15	71	29	0	silty sand
16	-	-	-	
17	98	1	1	sand
18	44	18	38	clayey sand
19	84	8	8	sand
20	-	-	-	
21	88	7	5	sand
22	91	9	0	sand
23	90	5	5	sand
24	96	2	2	sand
25	75	13	12	sand
26	99	1	0	sand

- no data

(i) Nutrients

Phosphorus

The distribution of total phosphorus in sediments is shown in Figure 16. The mean background level for the area was 1.1 g/kg, a value slightly in excess of the MOE criterion (1 g/kg) for impaired sediments. The phosphorus levels throughout most of the study area were only slightly elevated ranging from a low of 0.71 g/kg to a high of 2.3 g/kg with a mean of 1.1 ± 0.4 g/kg. Zones of lower concentrations were found in the nearshore area of the river immediately north of the Genstar and DuPont outfalls. The phosphorus values in these areas ranged from 0.47 g/kg to 0.65 g/kg with a mean value of 0.57 ± 0.07 g/kg.

Nitrogen

The distribution of total Kjeldahl nitrogen is given in Figure 17. The background level for the study area was 0.96 g/kg. As expected, elevated values were found near the Genstar Chemical Limited outfall (2.4 g/kg) which discharges wastes high in nitrogenous compounds. The distribution of nitrogen in sediments suggests that the plume associated with Genstar Chemical Limited extends approximately 2 km downstream from the outfall. Nitrogen values in the plume zone, outside of the outfall locations, ranged from 1.0 - 1.4 g/kg with a mean of 1.2 ± 0.2 g/kg. The MOE criterion for nitrogen in sediments was exceeded only at the outfall locations, indicating that contamination of sediments by nitrogen is not severe.

(ii) Organics

COD

The distribution of COD (Figure 18) is similar to that of nitrogen. The highest value in the study area (90 g/kg) was recorded near the Genstar Chemical Limited outfall. Beyond that point, the plume extended downstream along the shore for a distance of approximately 2 km. COD values in the plume zone ranged from 40 g/kg to 60 g/kg with a mean of 51 ± 10 g/kg which marginally exceeds the MOE criterion of 50 g/kg.

Organic Content

It is generally accepted (personal communication J. Hipfner) that organic content in sediments is equivalent to approximately half of the loss on ignition levels. Loss on ignition levels for the study area are given in Figure 19. The background was 3.4% and the highest value (8.8%) was recorded at the Genstar outfall. The plume associated with this outfall was localized and confined to the shore, and did not extend beyond the 2 m depth contour.

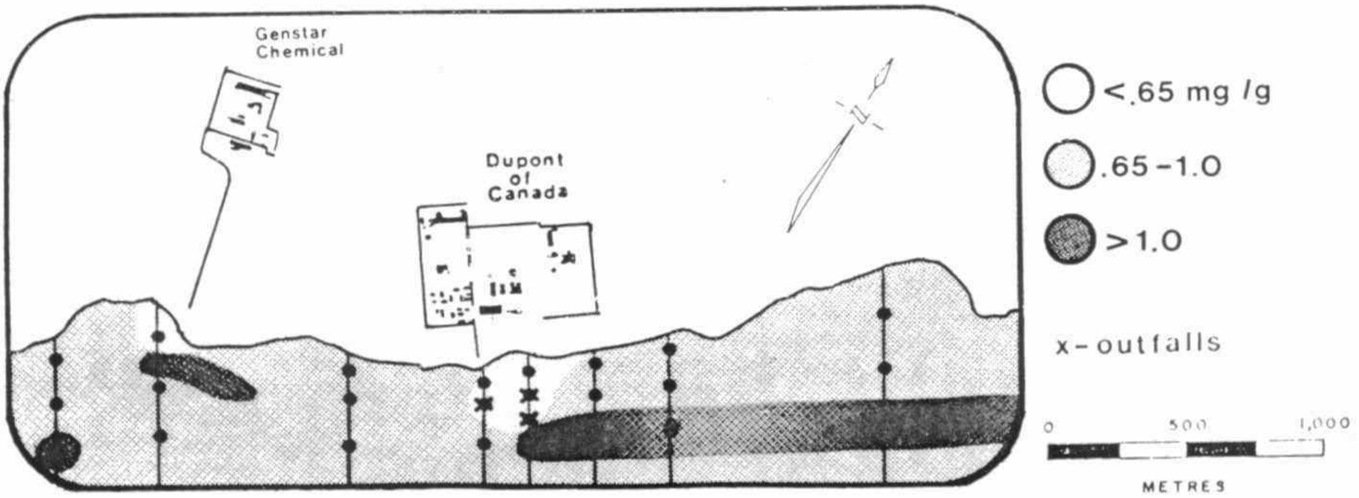


FIG. 16 Distribution of Total Phosphorus in Sediments

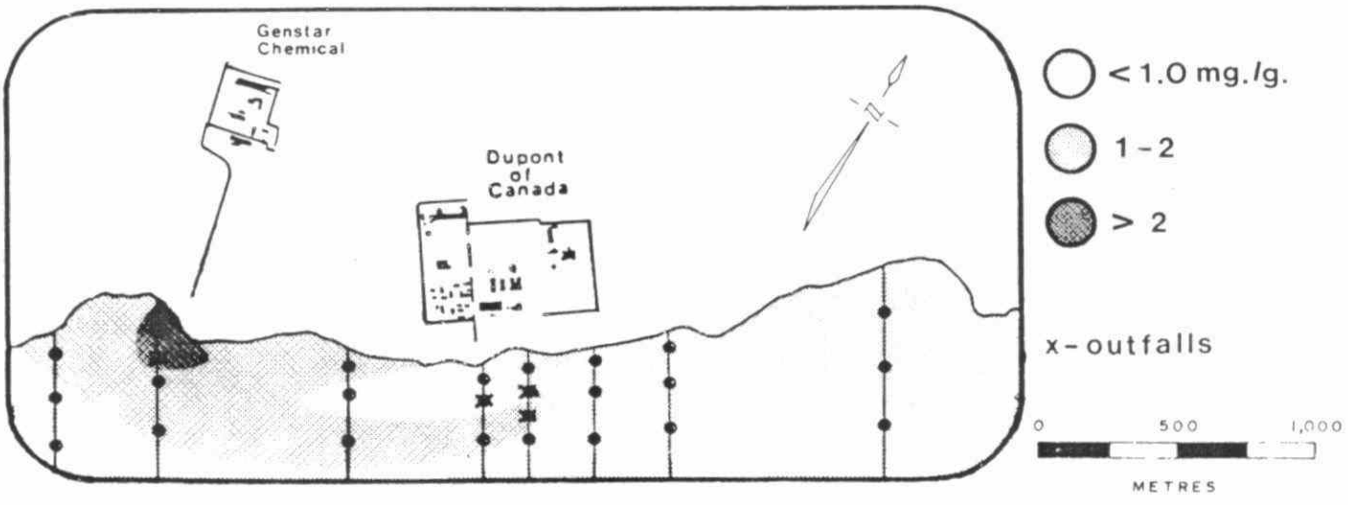


FIG. 17 Distribution of Total Kjeldahl Nitrogen in Sediments

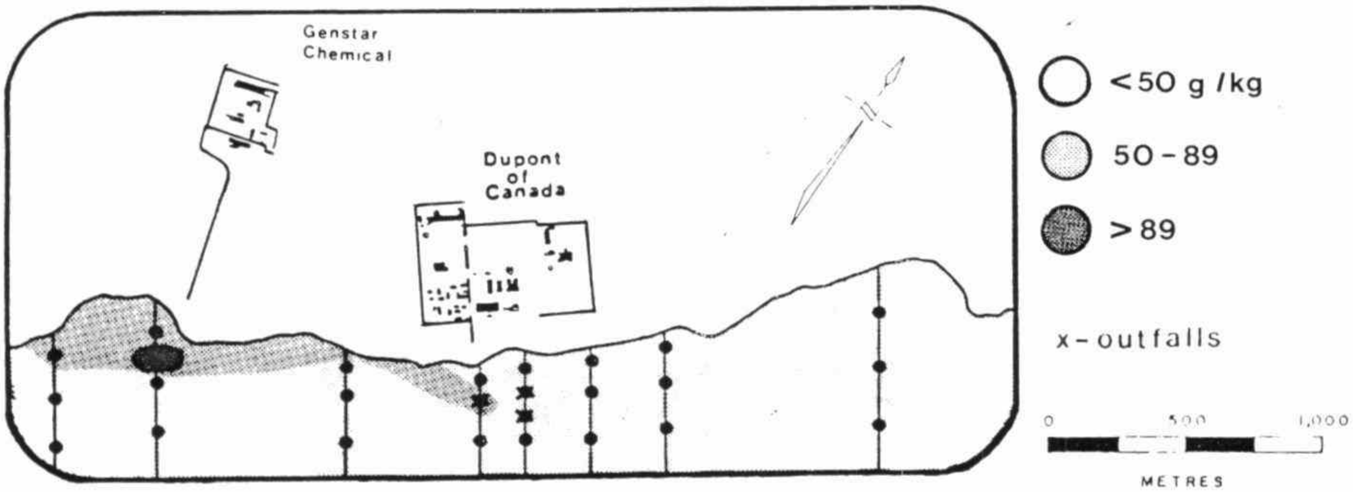


FIG. 18 Distribution of COD in Sediments

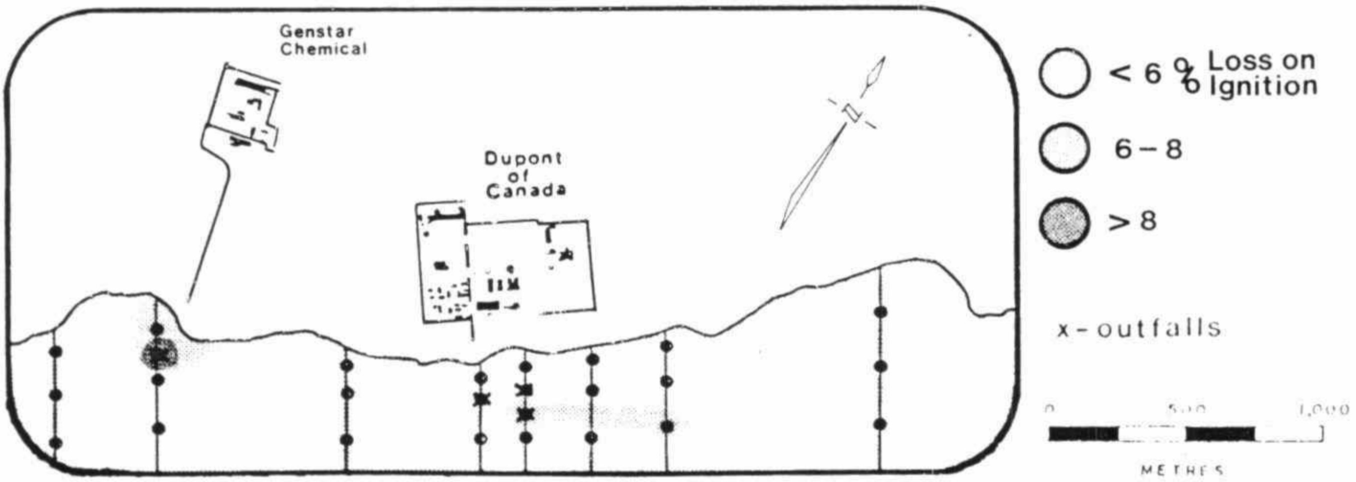


FIG. 19 Distribution of Organic Content in Sediments

A more extensive organic plume was found to be associated with the old DuPont monomer process wastes outfall. This plume extended for a distance of approximately 1 km and was detected at the 9 m as well as the 18 m depth contour. The organic carbon values in the two plumes ranged from 6% to 6.7% with a mean of 6.2% ± 0.4%, slightly exceeding the MOE criterion of 6%.

(iii) Heavy Metals

Several heavy metals are used in the production of nylon monomer intermediates and tetraethyl lead at DuPont. Zinc is used as a catalyst in the production of nylon intemediates. Cobalt, used in this process prior to 1970, has since been replaced by iron. Lead is a main component of tetraethyl lead production.

The Ministry is not aware of any heavy metals presently used in the manufacturing process of Genstar Chemicals Limited. However, since high levels of mercury, copper, zinc and lead have been found in sediments adjacent to a Genstar outfall, it is possible that either these were released in the past in conjunction with the use of contaminated caustic materials or that some unknown source of heavy metals is still discharged from the plant.

Data obtained in this study suggest that heavy metals in sediments can be used as tracers in estimating plume configurations arising from the various outfalls in the area. The background levels for the study area are as follows: Cu 17 ug/g, Zn 54 ug/g, Hg 0.07 ug/g, Pb 13.8 ug/g, Co 4.9 ug/g, Fe 17 g/kg.

The Genstar Chemical Limited effluent plume can be traced through the distribution of copper, zinc, mercury and lead in sediments (Figure 20-23). The extent of contamination by these heavy metals appears to be small since the plume is localized and cannot be detected 1 km downstream from the outfall. The levels at the outfall are highly elevated (Cu 49 mg/kg, Zn 278 mg/kg, Hg 2.5 mg/kg, Pb 55 mg/kg) and exceed the Ministry and EPA criteria.

The detection of plume configurations resulting from the DuPont outfalls is complicated by outfall proximity and locational change just prior to this study.

The tetraethyl lead effluent plume can best be determined through a study of lead distribution in sediments (Figure 23). The plume extends northeastward and affects the sediments from the 2 m to 9 m depth contour. The lead level at the outfall is 190 mg/kg, which is well above the EPA criterion of 50 mg/kg.

The plume associated with the old monomer process wastes outfall can be decribed by distribution patterns of Co, Zn, and Fe in the sediments (Figure 24, 21, 25). The distribution of these heavy metals trace the source of their emission to the old monomer outfall rather than to the newly installed outfall.

Two explanations are possible.

1. The treatment of the process wastes is effective in removing these heavy metals;
2. The short operation time of the new outfall (6 months to time of survey) was not sufficient to permit a substantial accumulation of metals in sediments.

The plume associated with the old monomer outfall did not appear to follow the 9 m contour but jetted out into deeper waters. It is a significant finding of this study that this plume was more extensive than previously suspected (Beak 1965, 1969, 1970) and likely extended beyond the study area.

The following mean levels of heavy metals were found in the plume zone: Co 21.8 mg/kg ± 6.4, Zn 83 mg/kg ± 15, Fe 95.6 g/kg ± 52. Iron was the only heavy metal found to be naturally high in the deeper (18 m) portions of the river. The mean iron value along the 18 m contour upstream from the old monomer outfall was 26.7 g/kg as compared to a mean of 7.8 g/kg found in the nearshore region.

The distribution of copper in the vicinity of DuPont outfalls is not clear. The highest level of copper (278 mg/kg) was discovered at the old monomer process wastes outfall and a localized plume was detected extending eastward for a distance of less than 500 m (Figure 20). Elevated copper levels upstream from the old monomer outfall suggest either that copper is emitted in the tetraethyl lead process or is released in treated monomer wastes.

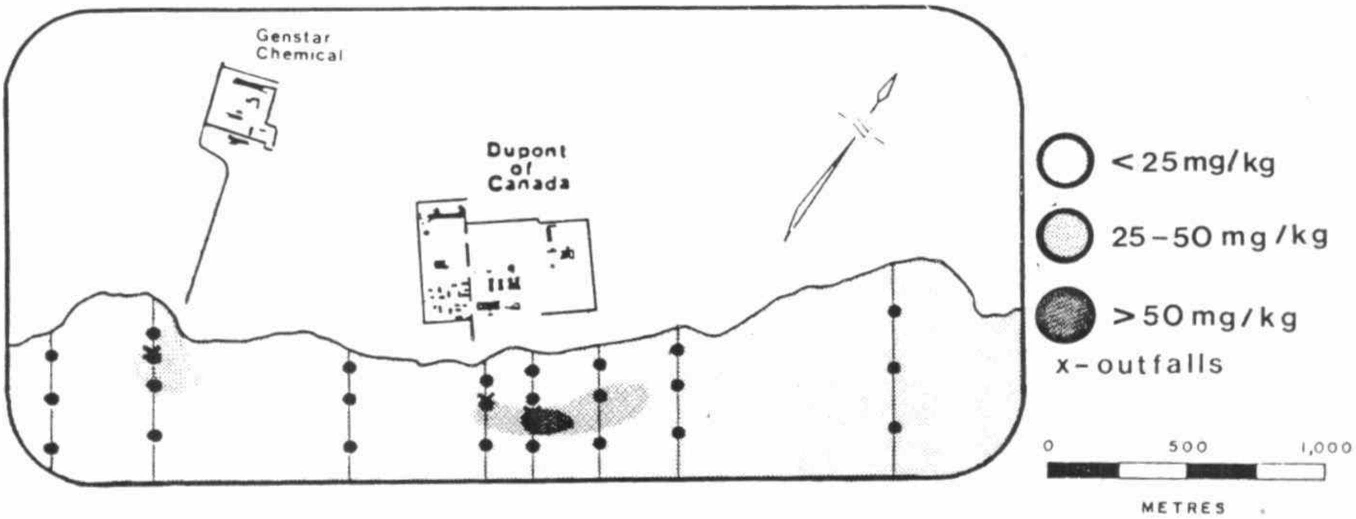


FIG. 20 Distribution of Copper in Sediments

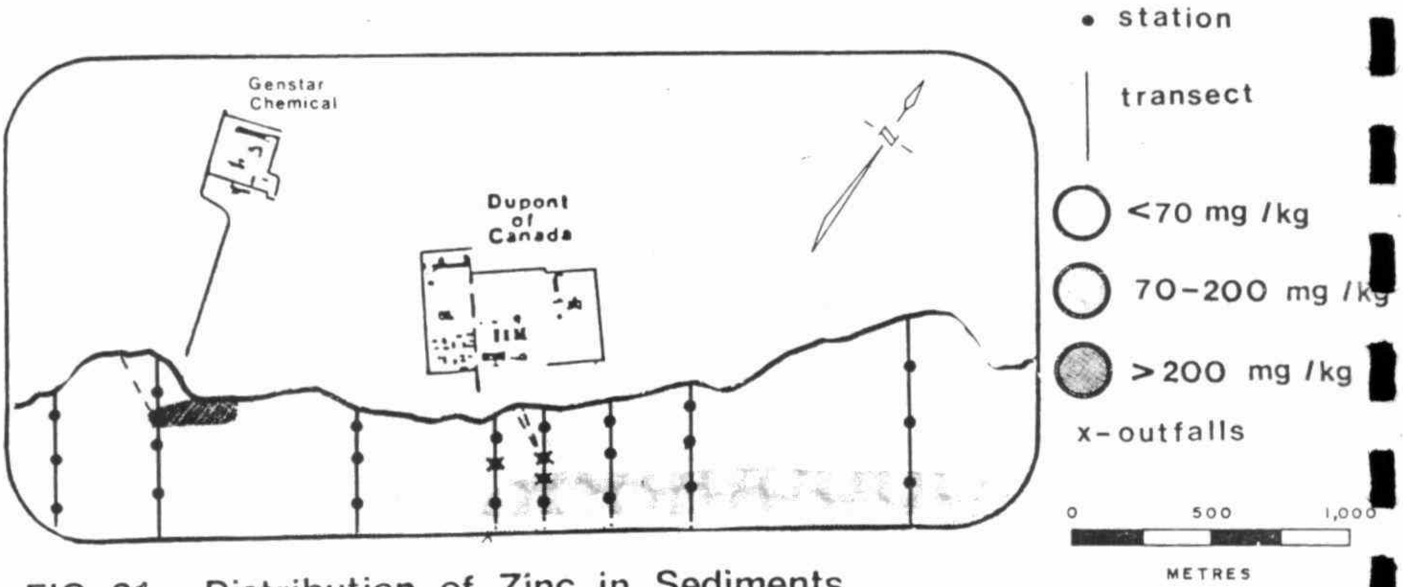


FIG. 21 Distribution of Zinc in Sediments

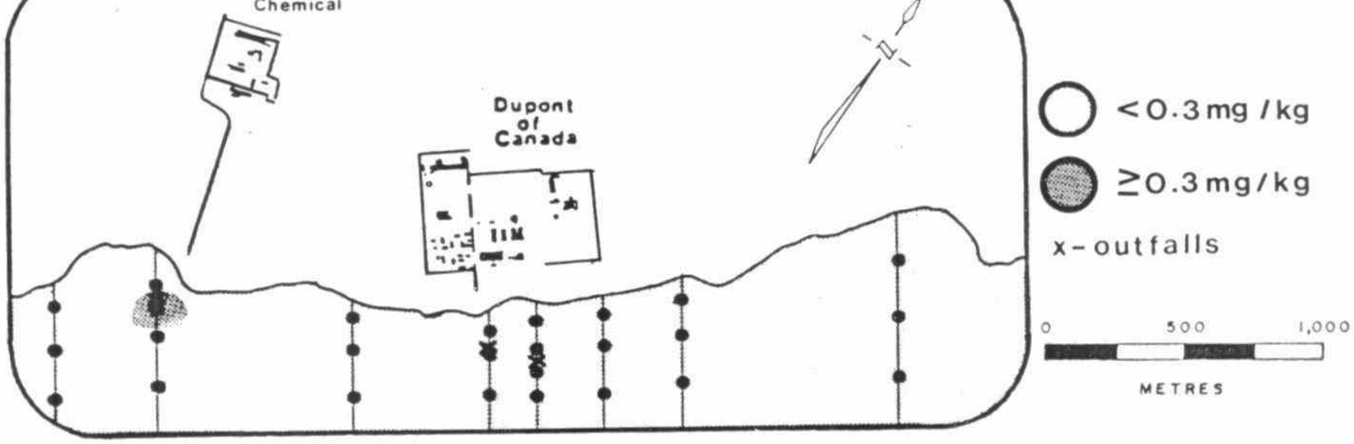


FIG. 22 Distribution of Mercury in Sediments

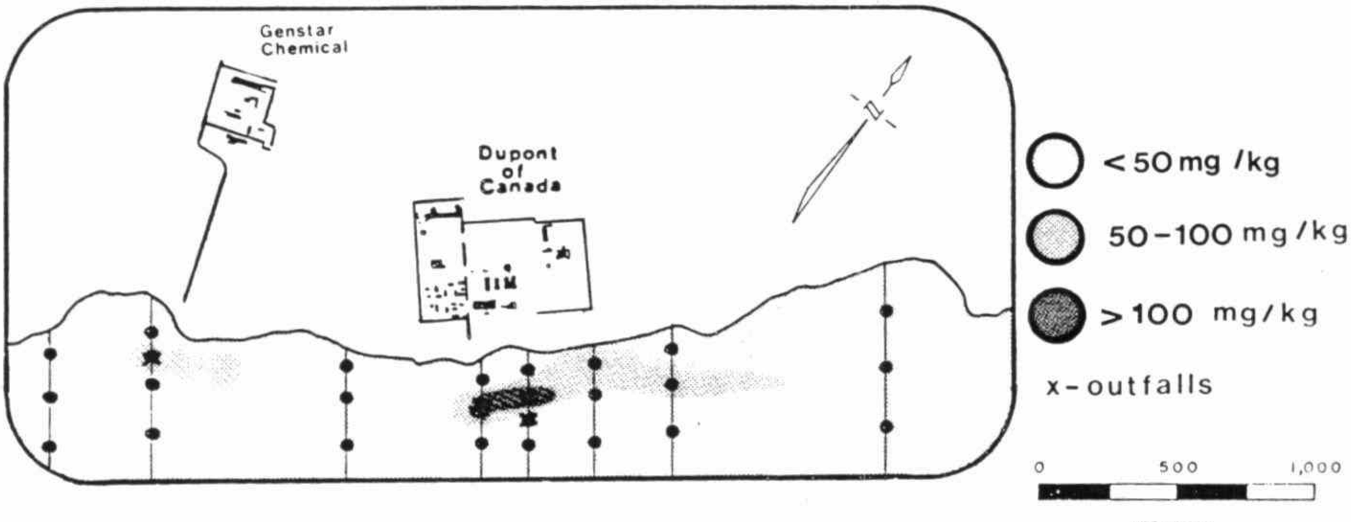


FIG. 23 Distribution of Lead in Sediments

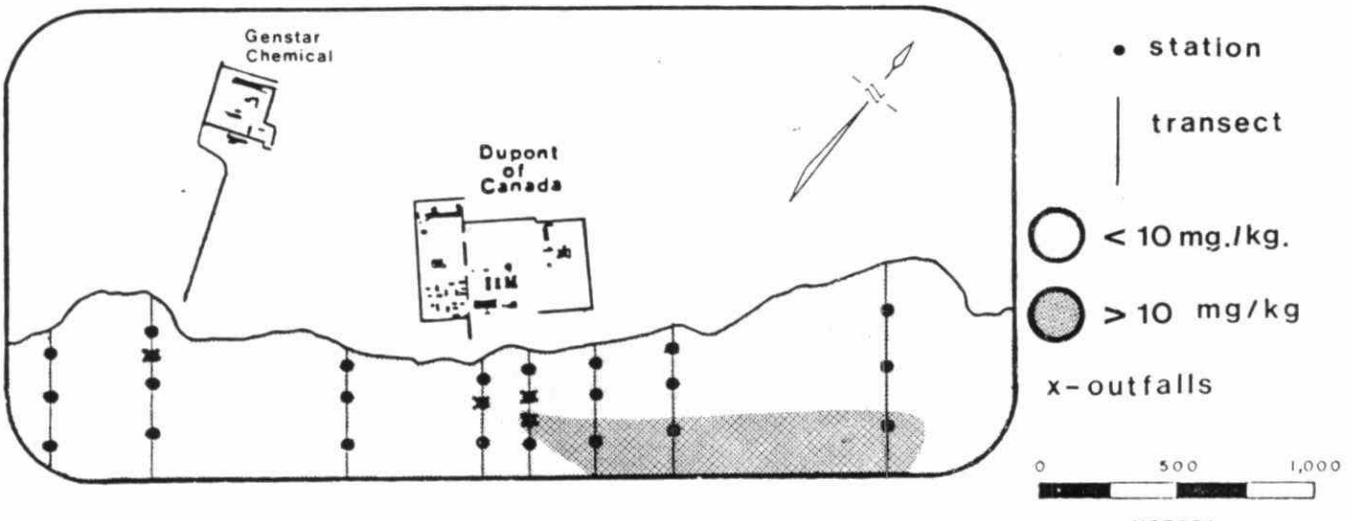


FIG. 24 Distribution of Cobalt in Sediments

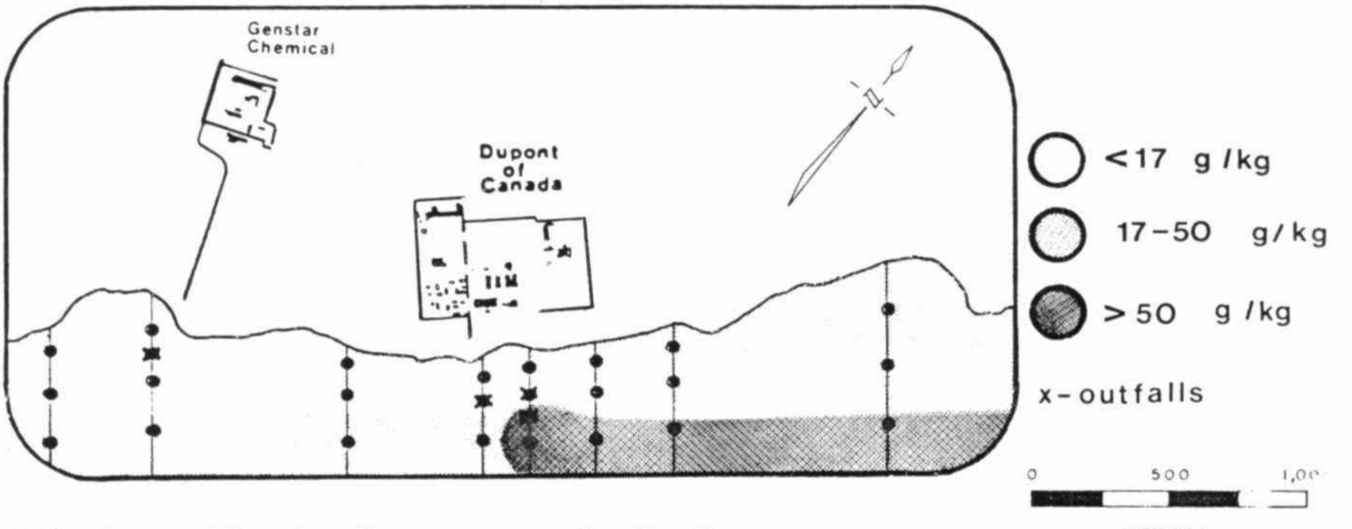


FIG. 25 Distribution of Iron in Sediments

III BENTHOS

(a) Control Zone Upstream From Industrial Discharges

The DuPont effluents have been shown to be lethal to rainbow trout (pers. comm. J. Munro, MOE). One of the aims of this report is to establish the effects of these effluents on the composition of the benthic community in the area.

The benthic invertebrates upstream from the industrial discharges fall within three discrete, depth related communities:

1. Shallow (2 m depth) nearshore community characterized by high species diversity (Figure 26) and large number of taxa (Figure 27);
2. Intermediate (9 m depth) community of high species diversity but moderate number of taxa;
3. Deep (18 m depth) community of low species diversity and moderate number of taxa.

The nearshore community is weakly dominated by the amphipod Gammarus fasciatus and by the midge Chironomus. The intermediate zone shows weak dominance by Gammarus fasciatus and Limnodrilus hoffmeisteri while the offshore zone is very strongly dominated by the snail Bithynia tentaculata which occurs in densities of approximately 10,000 individuals/m^2.

The response of the invertebrate community to industrial discharges will be discussed in the light of these depth dependent communities. The distribution of most common invertebrate classes and species (taxa) along depth contours is compared to that recorded at outfall locations in Tables 2 and 3. A detailed documentation of species distribution and numbers is presented in Appendix B.

(b) Effect of Genstar Chemical Limited Effluent on Zoobenthos

The benthic community at Genstar Chemical Limited outfall was characterized by a reduced species diversity (0.7), depressed number of taxa (7) and low density of invertebrates (90 individuals/m^2) (Figure 26, 27). The community was dominated by a tolerant oligochaete species, Limnodrilus hoffmeisteri. This species was found in reduced numbers compared to those found upstream from the discharge suggesting that even the most tolerant species were adversely affected by the effluent. Reduced populations of the amphipod Gammarus fasciatus and midges were also recorded at that location (Table 2, 3).

The zone of influence associated with Genstar Chemical Limited effluent extends at least 1 km downstream from the outfall and can be traced by a reduction of taxa numbers (Figure 27). Diversity index analysis suggests that this zone is confined to the shallower (9 m) region of the river (Figure 26) and that it approximates the distribution of nitrogen and COD found in sediments (Figure 17, 18). There exists the possibility that the zone of influence may extend as far as the DuPont tetraethyl lead outfall. Further study is necessary to investigate this possibility.

(c) Effect of DuPont Effluents on Zoobenthos

The immediate effects of the DuPont tetraethyl lead (TEL) and monomer outfall discharges are more severe than that of Genstar Chemical Limited.

The benthic community at the TEL and monomer outfalls was severely depressed being represented by only three species and therefore characterized by very low (0.1) species diversity. The community was dominated by *Limnodrilus hoffmeisteri*, which is known to be an opportunistic species becoming successfully established in the absence of other invertebrate forms. *Limnodrilus* densities at the outfall were somewhat higher than those found outside of the outfall at a comparable depth, reflecting the opportunistic success of this organism.

The areal extent of impact of the TEL and monomer effluents on the benthos can be detected best through an analysis of species diversity. The zone of depressed diversity (Figure 26) extends north-east from the outfalls and closely follows the distribution of lead (Figure 23) found in the sediments. This analysis suggests that the effect of the TEL effluent is localized and the zone of influence extends approximately 500 m along the north shore. *Limnodrilus hoffmeisteri*, snail *Pisidium* and clam *Valvata sincera* were the three dominant taxa characterizing this zone. The numbers of the amphipod *Gammarus fasciatus*, which was common in the unaffected nearshore region of the river, were severely depressed in the zone of influence. Effluent presently discharged through the TEL and monomer outfalls together with the contaminants found in the sediments are undoubtedly responsible for the observed toxicity.

The most severe toxicity to the benthic fauna in the study area was recorded downstream from the former monomer wastes outfall. Greatest toxicity was observed at the outfall location where only the amphipod *Gammarus fasciatus* was found to be capable of surviving. It appears that this species is tolerant of high levels of copper (278 ug/g) and cobalt (28 ug/g) found in the sediments at this outfall location. Its loose association and free swimming ability are the most likely explanations for its survival capability. Absence of effluent discharge at that location, following outfall relocation, is likely an important factor in the apparent tolerance of *Gammarus* to the conditions found at the old monomer outfall.

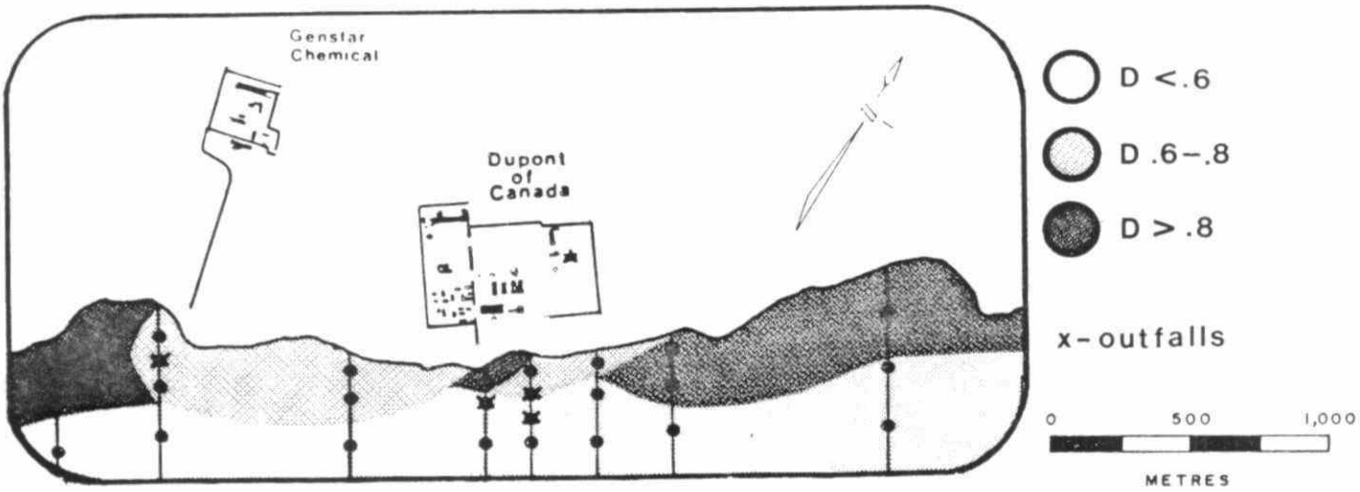


FIG. 26 Diversity Index (D) "Simpson-Gini" of Benthic Fauna

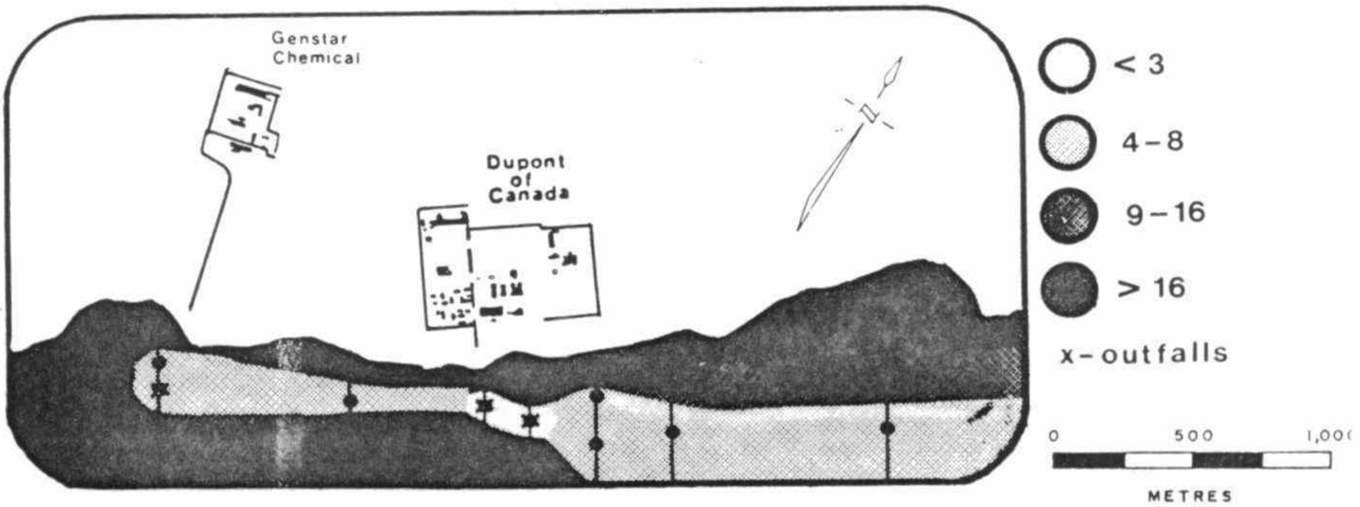


FIG. 27 Number of Invertebrate Taxa

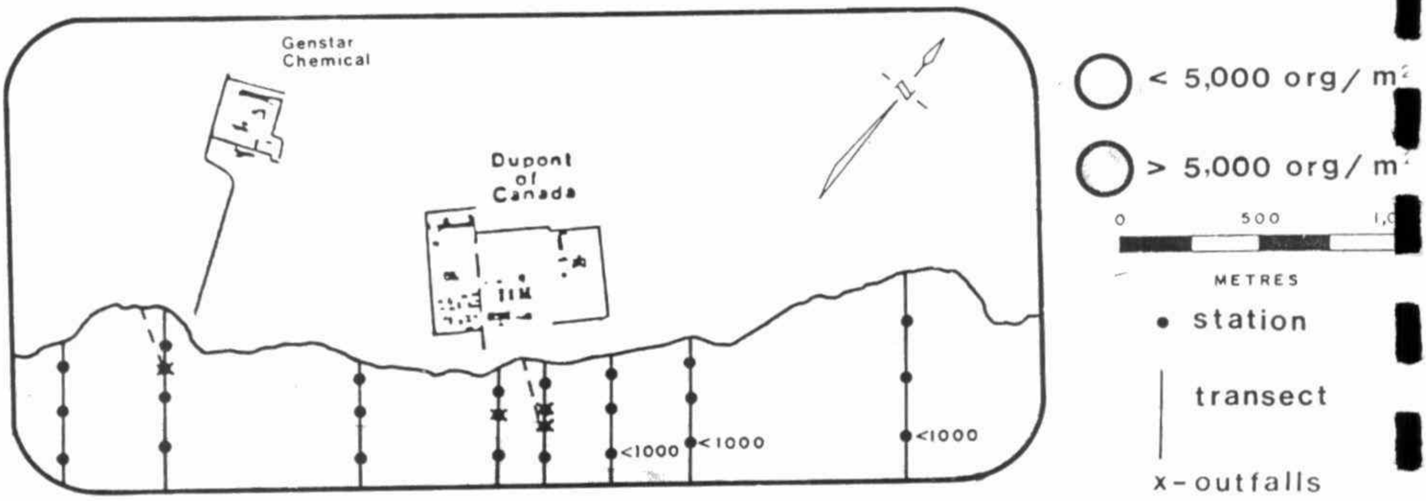


FIG. 28 Density of Bithynia tentaculata

TABLE 2 DISTRIBUTION OF INVERTEBRATE CLASSES ALONG DEPTH CONTOURS AND AT OUTFALL LOCATIONS AT MAITLAND ST. LAWRENCE RIVER, 1975

	Average Number Individuals/m^2					
TAXA	2m	9m	Genstar Outfall (9m)	DuPont Tetraethyl Lead Outfall (9m)	DuPont Old Monomer Wastes Outfall (9m)	18m
Oligochaeta (Sludgeworms)	180	220	51	459	0	73
Hirudinea (Leeches)	15	11	5	0	0	22
Crustacea (Amphipods)	320	93	5	19	230	190
Insecta (Midges)	260	43	5	0	0	<1
Gastropoda (Snails)	130	64	39	0	0	5000
Pelecypoda (Clams)	51	34	0	19	0	150

TABLE 3 DISTRIBUTION OF MOST COMMON INVERTEBRATES ALONG DEPTH CONTOURS AND AT OUTFALL LOCATIONS AT MAITLAND ST. LAWRENCE RIVER, 1975

	Average Number Individuals / m^2					
TAXA	2m	9m	Genstar Outfall (9m)	DuPont Tetraethyl Lead Outfall (9m)	DuPont Old Monomer Wastes Outfall (9m)	18m
Limnodrilus hoffmeisteri	170	220	51	459	0	5
Peloscolex ferox	16	3	0	0	0	53
Stylodrilus heringianus	1	0	0	0	0	13
Helobdella triserialis	10	4	0	0	0	< 1
Glossiphonia heteroclita	4	0	5	0	0	22
Gammarus fasciatus	240	83	5	19	280	190
Hyalella azteca	70	7	0	0	0	0
Midges	260	43	5	0	0	0
Bithynia tentaculata	6	45	22	0	0	5000
Valvata sincera	95	6	17	0	0	0
Sphaerium	14	9	0	0	0	110

Severely depressed species diversity (0.3) was also found as far as 250 m downstream from the outfall in 9 m of water. The sharp reduction of species in this zone is likely due to the combined effects of the TEL and old monomer outfalls.

The main effect of the old monomer wastes effluent can be traced in the deeper regions of the river (18 m depth contour). The distribution of the snail *Bithynia tentaculata* provides the most striking example of effluent toxicity in this zone (Figure 28). Upstream from the old monomer outfall, *Bithynia* densities were found to be between 5,000 and 10,000 individuals/m^2. Downstream from the monomer plume, *Bithynia* numbers became greatly reduced ranging in numbers from 100 to 900 individuals/m^2. No recovery was evident in the farthest station sampled, located 2 km from the outfall. This finding is significant for it traces the effect of the old monomer effluent into the deeper regions of the river, and for the first time documents the dramatic toxicity to the most abundant invertebrate species in the study area. The cause of the toxicity appears to be associated with high heavy metal levels and low pH of the effluent. Despite numerous reports documenting the effect of this outfall in the past (Beak 1965, 1969, 1970), none were successful in tracing the full effect of the effluent or correctly defining its zone of influence.

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APPENDICES

Appendix A

TABLE 1a:

Nutrients and Heavy Metals in Sediments at Maitland, St. Lawrence River, 1975.

Station Number	% Loss Ignition	COD g/kg	P g/kg	N g/kg	Cu mg/kg	Co mg/kg	Cd mg/kg	Zn mg/kg	Fe g/kg	Pb mg/kg	Hg mg/kg
1	3.4	15	1.5	0.68	13	8.8	<1	61	36.5	8.5	0.04
2	2.4	35	0.83	0.91	20	3.0	<1	58	8.3	18	0.10
3	4.3	50	0.98	1.30	17	3.0	<1	43	7.2	15	0.09
4	3.3	30	0.86	1.00	17	4.0	4	61	18.6	14	0.08
5	3.4	40	0.73	1.10	29	4.0	<1	61	8.7	21	0.21
6	8.8	90	1.25	2.40	49	3.0	<1	278	10.8	55	2.50
7	6.0	60	0.61	2.30	25	3.5	<1	50	15.3	13	<0.01
8	3.9	30	0.95	1.00	11	4.5	<1	61	25.0	18	0.06
9	3.0	15	0.87	0.65	16	<2.9	<1	50	4.2	11	0.06
10	3.4	47	0.71	1.30	23	<3.0	<1	53	5.3	17	0.10
11	4.0	33	0.85	1.00	23	6.8	<1	80	26.8	25	0.06
12	2.1	60	0.60	0.77	36	3.9	<1	34	16.4	190	0.01
13	2.5	20	0.65	0.60	13	<3.0	<1	23	6.5	25	0.01
14	3.6	24	1.40	0.69	18	12.0	<1	88	55.6	24	0.06
15	6.7	16	0.50	1.40	278	28.0	<1	80	167.0	19	0.05
16	1.0	5	0.61	0.39	22	7.0	<1	26	4.2	119	0.06
17	1.1	10	0.47	0.45	10	7.2	<1	16	4.5	32	0.06
18	3.9	10	1.20	0.47	17	26.0	<1	70	58.0	11	<0.01
19	2.1	20	0.93	0.67	36	8.5	<1	16	8.8	48	<0.12
20	2.2	15	0.79	0.80	21	6.0	<1	33	3.1	64	0.05
21	6.0	15	2.30	0.44	18	24.0	<1	110	135.0	11	0.06
22	2.7	20	0.85	0.76	20	8.0	<1	55	8.6	51	0.08
23	2.4	25	0.65	0.79	16	<4.3	<1	28	2.7	37	0.04
24	3.5	20	1.40	0.32	12	19.0	<1	70	59.4	6.5	0.04
25	3.2	35	0.95	0.88	16	8.8	<1	40	10.4	20	0.10
26	<1.0	6	0.73	0.22	4	<5.0	<1	6.5	1.8	5	0.02

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7
Flatworms	Planariidae sp	17	11					
Nematodes	Nemata sp						8	11
Sludgeworms	Limnodrilus hoffmeisteri	5	72	140	104	275	51	17
	Peloscolex ferox	116	5	8	27			
	Stylodrilus heringianus							
	Oligochaeta sp							
Leeches	Helobdella triserialis							
	H. stagnalis		43	5				
	Glossiphonia heteroclita	24		5	35		5	
Copepodes	Copepoda sp							
Shrimps	Gammarus fasciatus	381	107	449	233	178	5	251
	Hyalella azteca		5	17				5
	Asellus militaris			49				
Insect	Agrion sp							5
	Coleoptera sp							
	Agraylea sp							5

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7
Midges	Chironomus sp			405			5	5
	Parachironomus sp							
	Cryptochironomus sp		43	140		72		5
	Glyptotendipes sp		8	91				16
	Stictochironomus sp							
	Tribelos sp							
	Procladius sp	5	19	5				
	Tanytarsus sp							
	Orthocladiinae sp							
	Dicrotendipes sp			215				
	Monodiamesa sp			11				
	Polypedilum sp		5					
	Psectrocladius			78				
Water mite	Acari sp			8				
Snails	Bithynia tentaculata	9905	38	16	9014	8	22	
	Valvata sincera			99			17	
	V. tricarinata							
	Promentus exacuous							
	Gyraulus deflectus							
	Amnicola limosa					5		16
	Physa gyrina	5		51				
	Lymnaea sp	35	16		5			

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7
Snails cont'd	Compelona decisum							
	Goniobasis liveseens							
Clams	Pisidium compressum	46		5	29	5		11
	P. variable	15	5			8		5
	Sphaerium simile	368		5	101			11
	S. striatinum	5						
	Ellipto complanata	24	39	5	19			

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Stn 13	Stn 14
Flatworms	Planariidae sp		5		122			35
Nematodes	Nemata sp					8		
Sludgeworms	Limnodrilus hoffmeisteri			19		19	21	
	Peloscolex ferox	55			90	124		30
	Stylodrilus heringianus				8	16		43
	Oligochaeta sp	5					5	
Leeches	Helobdella triserialis	5		5			5	
	H. stagnalis							
	Glossiphonia heteroclita	28		22	35	5		43
Copepodes	Copepoda sp							
Shrimps	Gammarus fasciatus	58	147	1066	325	43	11	115
	Hyalella azteca			214				
	Asellus militaris			76		5		
Insect	Agrion sp							
	Coleoptera sp			13				
	Agraylea sp							

TABLE 2 a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Stn 13	Stn 14
Midges	Chironomus sp						19	
	Parachironomus sp							
	Cryptochironomus sp			5			87	
	Glyptotendipes sp			25			5	
	Stictochironomus sp						16	
	Tribelos sp							
	Procladius sp							
	Tanytarsus sp			46		11	8	
	Orthocladiinae sp			5				
	Dicrotendipes sp			74				
	Monodiamesa sp							
	Polypedilum sp							
	Psectrocladius							
Water mite	Acari sp			5				
Snails	Bithynia tentaculata	4972	220	28	9613	8		5202
	Valvata sincera			65			13	
	V. tricarinata			5				
	Promentus exacuous							
	Gyraulus deflectus			8				
	Amnicola limosa			11				
	Physa gyrina		5	58				
	Lymnaea sp	5			40			8

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES
AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 8	Stn 9	Stn 10	Stn 11	Stn 12	Stn 13	Stn 14
Snails cont'd	Compeloma decisum							
	Goniobasis liveseens		22	5				
Clams	Pisidium compressum	16	33	65	43	11	25	29
	P. variable		8	57		5		
	Sphaerium simile	30	32	55	170	21		125
	S. striatinum							
	Ellipto complanata	11		5	25			5

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 15	Stn 16	Stn 17	Stn 18	Stn 19	Stn 20	Stn 21
Flatworms	Planariidae sp	5			13			
Nematodes	Nemata sp						5	
Sludgeworms	Limnodrilus hoffmeisteri	5	19	333		333	239	31
	Peloscolex ferox			114	5			24
	Stylodrilus heringianus						8	8
	Oligochaeta sp			5				
Leeches	Helobdella triserialis			11			22	
	H. stagnalis							
	Glossiphonia heteroclita				8			
Copepodes	Copepoda sp							
Shrimps	Gammarus fasciatus	35	35		55	8	8	105
	Hyalella azteca						8	
	Asellus militaris							
Insect	Agrion sp							
	Coleoptera sp							
	Agraylea sp							

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES
AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 15	Stn 16	Stn 17	Stn 18	Stn 19	Stn 20	Stn 21
Midges	Chironomus sp			8		171		
	Parachironomus sp			11				
	Cryptochironomus sp							
	Glyptotendipes sp							
	Stictochironomus sp							
	Tribelos sp			5				
	Procladius sp						5	
	Tanytarsus sp							
	Orthocladiinae sp							
	Dicrotendipes sp							
	Monodiamesa sp							
	Polypedilum sp							
	Psectrocladius							
Water mite	Acari sp			5				
Snails	Bithynia tentaculata		5		975			423
	Valvata sincera			69			388	
	V. tricarinata							
	Promentus exacuous							
	Gyraulus deflectus			16				
	Amnicola limosa					19		
	Physa gyrina						11	
	Lymnaea sp							

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 15	Stn 16	Stn 17	Stn 18	Stn 19	Stn 20	Stn 21
Snails con't	Compelona decisum							
	Goniobasis liveseens							
Clams	Pisidium compressum		77	5	8			
	P. variable			24		28	36	5
	Sphaerium simile		24		29	11	5	22
	S. striatinum							
	Ellipto complanata				5			11

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES
AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 22	Stn 23	Stn 24	Stn 25	Stn 26		
Flatworms	Planariidae sp			5				
Nematodes	Nemata sp		8			31		
Sludgeworms	Limnodrilus hoffmeisteri	36	475		598	82		
	Peloscolex ferox	11	8					
	Stylodrilus heringianus			16				
	Oligochaeta sp							
Leeches	Helobdella triserialis		21		22	16		
	H. stagnalis							
	Glossiphonia heteroclita					5		
Copepodes	Copepoda sp	5						
Shrimps	Gammarus fasciatus	36	55	252	19	44		
	Hyalella azteca		72		39	243		
	Asellus militaris				19	8		
Insect	Agrion sp							
	Coleoptera sp		5			5		
	Agraylea sp					39		

TABLE 2a

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DISTRIBUTION OF BENTHIC INVERTEBRATES
AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 22	Stn 23	Stn 24	Stn 25	Stn 26		
Midges	Chironomus sp	5	124		80	282		
	Parachironomus sp							
	Cryptochironomus sp	5			17	5		
	Glyptotendipes sp		16					
	Stictochironomus sp							
	Tribelos sp							
	Procladius sp					17		
	Tanytarsus sp		68					
	Orthocladiinae sp							
	Dicrotendipes sp							
	Monodiamesa sp							
	Polypedilum sp							
	Psectrocladius		37					
Water mite	Acari sp					5		
Snails	Bithynia tentaculata	5	5	183				
	Valvata sincera		75		36	47		
	V. tricarinata							
	Promentus exacuous		5					
	Gyraulus deflectus							
	Amnicola limosa		5			5		
	Physa gyrina		21	5	5			
	Lymnaea sp							

TABLE 2a

APPENDIX B

DISTRIBUTION OF BENTHIC INVERTEBRATES
AT MAITLAND, ST. LAWRENCE R. 1975

Zoobenthic Group	Species	Numbers of Individuals/m^2						
		Stn 22	Stn 23	Stn 24	Stn 25	Stn 26		
Snails cont'd	Compelona decisum	5						
	Goniobasis liveseens							
Clams	Pisidium compressum	13	30	5		11		
	P. variable		31		5	5		
	Sphaerium simile	5	5	17	5	5		
	S. striatinum							
	Ellipto complanata	5						